A Systematic Approach to Web-Application Development

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Abstract

Designing a web-application from a specification involves a series of well-planned and well-executed steps leading to the final product. This often involves critical changes in design while testing the application, which itself is slow and cumbersome. Traditional approaches either fully automate the web-application development process, or let developers write everything from scratch. Our approach is based on a middle-ground, with precise control on the workflow and usage of a set of custom-made software tools to automate a significant part of code generation.

1 Introduction

Web-application development is always a challenging task at hand. With the ever changing internet technologies it is difficult to master a particular technique and keep it running without the risk of being too outdated and incompatible with future technologies. While there are sophisticated frameworks for large scale web-application development, lack of time-tested proofs of their reliability and maintainability is still an issue with using them. Maintaining an existing piece of software is much more important because it is directly related to the cost of it. Choosing a middle ground here proves to be rational. A simpler framework with more code to write from scratch can be helped by developing software tools to automate part of a large common code base which is otherwise error prone if written by hand.

In our case, we have developed a medium scale web-application, the Stony Brook University Graduate Application Web-app, using entirely JSP/JavaBeans as the web technology.

While a sophisticated framework like Struts or Spring can drastically reduce the amount of code, the time to understand and master each of them can easily be inefficient for a medium scale project, supposed to be maintained and monitored by different batches of students.

2 Principles of task oriented Web design

2.1 Choice of framework

Choosing a framework for a particular web-application is much like choosing the right tool for a job. Often a mix-up of current technologies prove to the right one for the task at hand. It needs significant background and future maintenance scenario analysis before coming to a concrete choice. The maintenance scenario is extremely important here because if an application is not going to be maintained by a fulltime trained professional, a complex framework can easily spell disaster in the long run.

One of the most stable and widely used web application frameworks is the JSP/JavaBeans/Servlets. Simplicity is one of its major strengths. There are many modern frameworks widely used currently, like the Struts and the Spring frameworks, all of them employing the MVC model. There is also Hibernate, a database isolation layer used with the latter two frameworks which offers few high level advantages over JDBC at the cost of initial setup and complexity overhead.

We have chosen our MVC model based on the JSP/JavaBeans/Servlets framework and resorted to JDBC for all communication with the Oracle database backend.

2.2 Design of page flows

Designing the flow of an application with primarily human interfacing (a web page with choice of operations) is inherently a task involving intuitive thinking. At the same time, the flow has to blend well with the backend where the data is processed. There is inherently a tradeoff when it comes to efficiency. In our case more emphasis is given to the intuitive page flow at the cost of adapting the backend to work with it. At the same time it has been kept simple by minimal use of session-saved attributes.

An example is shown as follows. The scenario is of a new user attempting to start an application process. The user’s new email and password must be setup before everything else,
so a page with email and password information is presented to him/her. When the user fills the form, an email is sent to the given email address to verify its correctness. The email has a link which when clicked, confirms the user as authentic and is allowed to proceed filling up other details in the subsequent pages.

3 The Design of Graduate Application Webapp (GAW)

3.1 Architecture

We made a generic architecture for the class of web applications that concern online applications to universities. The advent of internet and e-commercialization of everything has lead the path to adhoc web application development. With a systematic development approach and architecture our goal is to make such application developments more predictable and easier to build.

3.1.1 Users

We can divide the users of a graduate application system in a few major classes. At the bottommost level, prospective students will be using it to apply to graduate school. Graduate school employees can access the student records and if needed, can modify some fields. Reviewers, assigned by the graduate school, who are normally professors in the university can review the resumes, transcripts and statements of purpose to comment on the students’ chances of getting admitted. Graduate directors can assign graduate school employees for access on the student records. There can multiple graduate directors. At the top level, the graduate application administrator can control everything about the system, primarily assigning graduate directors.

3.1.2 Subsystems

The identifiable subsystems are:

- **Database interface** consisting of the methods to communicate with the Oracle backend.
- **Client (user) interface** which is basically the jsp pages and makes the "View" part of the MVC model.
- **The beans** as the system "Model" with client input validation logic.
- **The servlets and managers** as the "Controller" of the system with the page flow logic.

3.2 Application subsections

Here we discuss the form pages in the application process that an applicant has to fill up.

1. **General Information:** Applicant’s personal information like names, DoB, addresses and phone numbers are stored.
2. **Application Information:** The academic program, semester and attendance status is stored.
3. **Educational History:** Applicant’s previous education records such as college names, addresses, subjects, degrees and GPAs are stored.
4. **Employment History:** Applicant’s previous employment records such as company names, addresses, positions and work dates are stored.
5. **Qualifications:** Additional credentials like journal articles, conference papers, project reports are entered here.
6. **Test Scores:** Test and score information of a varied number of tests (e.g., GRE/TOEFL) that the applicant had taken are stored.
7. **Language Proficiency**: Information about proficiency in English of international applicants are entered.

8. **Financial Aid**: Applicants report if they received fellowships like AGEP, EOP, SEEK etc.

9. **Resume and Statement of Purpose**: Applicants can either upload their resume/sop in any well-known format (.txt, .doc, .pdf etc) or can type it in the input area provided.

10. **Recommendations**: Information about recommenders are put by the applicant. Later when the recommenders fill up the recommendation text they also enter comments on the applicant’s academic performance and motivation and the chance of his/her being a potential TA in the department.

11. **Transcripts**: Applicants can either upload their transcript in any well-known format (.txt, .doc, .pdf etc) or can type it in the input area provided.

12. **Supplemental Department Applications**: Additional application information that are unique to each department are entered here.

13. **Check Applications**: Applicants can check for validity of their whole application process before submitting.

14. **Submit and Pay**: Applicants can pay using an international credit/debit card. The payment is done securely by using the service verisign which is a proven portal for secure third party payments.

### 3.3 Code hierarchy

To effectively handle a large code base, we have partitioned the Java code in manageable concepts or entities other than the JSP pages, namely `bean`, `manager`, `servlet` and `util` which are also the package names. The top level package is `gaw`. The package descriptions are briefly given below:

#### 3.3.1 gaw.bean

The bean classes correspond the tables in the database. The variables in a bean are one-to-one with the fields in the corresponding table. They basically act as containers for one row of data to be moved around the application. The beans are used in the JSP pages to populate the fields and to store data around session and are saved as session attributes for the duration of the active session.

#### 3.3.2 gaw.manager

The manager classes are designed as a layer between the beans and database, to perform the CRUD operations. In more complex frameworks this is where we have Hibernate, and much more powerful abstraction layer. Using the managers we retrieve a variety of table information, either one row corresponding to a primary key, or a set of rows satisfying some criteria.

#### 3.3.3 gaw.servlet

Servlets are part of the web-application framework we are using. These take the HTTP request coming from the forms in the JSP pages and control the page flow. They set the session attributes with the updated beans, call the managers to save or update the data and redirect to the next appropriate page. It also calls the validation routines in a bean before saving it and if the request page form has errors in one or more fields, the same page is redirected to again with the error list at the top of it.
3.3.4 gaw.utils

A set of utility classes are made, namely the DBConnectionPool, EmailHelper and ConfigReader to provide some of the basic core functionality.

The DBConnectionPool class provides the pooling of database connections. Currently a singleton JDBC connection object is used, but with increasing load in future, multiple connections can be kept open and load-balanced the use between them.

The EmailHelper class provides e-mail functionality with just a function call. The configurations for the email are externally specified in a configuration file. It is used to send mail to a new applicant to verify authenticity of his provided email to log in and use the system.

The ConfigReader class is essentially a tool to read a xml configuration file for various configurations of the system.

3.4 Functional specifications

In this section several key functionality of the system will be discussed, in the use-case level. The idea of intuitive page flows govern the majority of functional design. Many of the design decisions stem from common sense only.

- When a new prospective student applies for a graduate program, he is first required to input email address and password. A confirmation mail is then sent to the email address to verify its authenticity. when the user clicks the link in that mail, he becomes a confirmed user and can log in to the system to start the application process.
- An user can change his/her email address. Even though email should be unique, it is not a primary key because it is changeable. the primary key for a user is user_id, which once created, doesn’t change ever.
- All the jsp pages check the existence of a user email address in a session attribute, as they are all contextual, needing a valid user for the page content to be shown. If a session is not on, a message is shown requesting to log in first.
- If an applicant deletes his/her account, all the information about the account is still retained, only the email address is prefixed with a special word so that it can no longer be used.

4 Implementation

In this section several key approaches towards a systematic software development is discussed, focussed to web-applications. Naming fields, variables and methods is one of the most important task, given the finite short term memory capacity of human developers. This is closely followed by some custom software tools whenever code can be churned out mechanically, following a rule.

4.1 Design of the database

The database design follows the principle of generalization of all possible applications for graduate school. Besides having a separate table for login information which contains the email address and password of the user, this table also contains the user_id field. The user_id field is the unique identifier of the user in the whole system. This id is invisible to the user and cannot be updated if changed. In this way the user can change his login informations and email, operation which does not require any change in other database tables. Majority of tables in our design contains a primary key in the form of an id, which is auto generated, used to refer a row from other tables.
4.2 Naming

Naming variables is one of the most daunting tasks in any large scale software development. In most cases involving database tables, variables and methods closely depend on the fields in the tables. If the naming of variables is not done systematically, it is easy to make errors when dealing with tables, fields, variables and method names. In a web-application involving JSP/JavaBeans technology, a big component of the code is the beans where we practically have a one-to-one mapping of variables with the fields in the database tables.

In a web-application, many things depend on the field and table names in a database. Table names dictate bean class names and fields dictate bean variables, getter and setter method names.

A standard naming approach simplifies coding and recalling a number of variables and method names instantly from a field or table name. We used a formal naming approach as follows: if a database field is `first_name`, the corresponding variable name would be `firstName` and the getter/setter methods would be `getFirstName()` and `setFirstName()` respectively.

4.3 Code generation

A major part in a web-application based on JSP/JavaBeans is the development of the bean and the manager classes. A bean consists of a set of variables, usually corresponding to a set of fields in a database table and their respective getter and setter methods. There are also other added aspects like error checking approach embedded in the beans. We discuss it in a later subsection.

A manager is a controller class which takes care of the CRUD (create, retrieve, update, delete) operations of the beans with the database.

Coding of managers is a time-consuming and repetitive process and often prone to typographical errors. Errors with closely similar variable names are hard to detect and debug as they do not break compilation, so there must be some sort of automation to generate all the common code.

A tool called BeanHelper is developed for this particular task at hand. It helps with fragments of code concerning putting the bean variables in the database using a sql statement and retrieving them. We discuss more about it later.

4.4 MVC model

We employed a Model-View-Controller model on our approach. The main code is broken up in the following parts: jsp, beans, managers and servlets. Obviously the jsp pages constitute the "View" in the MVC model as they are interface of the system with the outer world. The beans hold the data and the logic for its validation, hence they are the "Model". The managers basically take care of the CRUD (Create-Retrieve-Update-Delete) interface of the user data with the database using the beans as data containers. The servlets receive the user requests when forms from the jsp pages are submitted and process them, using managers to interact with the database and control the session. So the managers and servlets constitute the "Controller".

4.5 Database interface

The quickest way to interface a database is using JDBC with a couple parameters. On the other hand in frameworks like Hibernate, there is an extensive tiering of configurable layers. In our system we made use of JDBC with parameters set using a simple XML configuration file.

We employed the concept of connection pooling to make use of load balancing later on when there are simultaneous activity and significant speed-up is achievable by several parallel connections to the database. At present only one connection object is created and is re-used between database connection open requests.

While saving a row of data from a bean to a table, the method in the manager class is called `saveOrUpdate()` because we have no information beforehand if the data is new or an update of
an existing row in the table. We check for the primary key for existence and depending on the outcome do either an insert or an update operation.

### 4.6 File uploads

For uploading files like resumes, statements of purposes and transcripts, we used a third party file upload library *Upload Bean*.[1]

Instead of writing code for modifying each individual tables about the upload status, this library helps reducing code duplication in a novel way. It uploads any file to a special table and provides us a key for the upload, i.e., an uploadId. We only put that uploadId in any application table which concerns the uploaded file. This made us write once one chunk of code for the upload, with the destination table information as the parameters.

### 4.7 Error validation with Java beans isValid methods

Checking for validity of every field in a form is one of the biggest drudgery in the coding of web-applications. This is also the often ignored part in the process but one of the most critical as well. Security errors can easily creep in in the form of SQL injections and other attacks if the fields are unchecked before processing the contents. There are tedious frameworks with formalized verification languages which can be in the jsp page itself, with custom tags, but this is out of our approach. In our method, instead of verifying the correctness of the input data in the "View", i.e., jsp pages, we put the validation logic in the "Model", i.e., the beans.

By default, a field is validated by checking if it is empty. More complex validations include date and country-state combinations. Tools are made to validate if a given date is after a configured "oldest possible" date or before the "newest possible" date. In country and state validations, it must be checked that "USA" as country choice is associated with a US-state from a drop down list and any other state is accompanied by a non-USA country.

#### 4.7.1 AJAX approach and its limitations

A significant part of today’s web applications are increasingly using a new technology - Asynchronous Javascript and XML (AJAX). We have been so far only familiar with the transfer of a whole web page from the server to a client, even in the event of a small change of data coming back to the client. This produces a significant delay in the feedback typically when client submits a form and the server sends the form back with fields containing invalid data in a different format, like in red color. Using AJAX this wasted time and bandwidth can be entirely eliminated.

However, all good things come with at least some drawbacks. Using AJAX without a design in mind introduces a problem with browser state. Simply put, the back button of the browser will no more retain its use in AJAX-enabled pages. For example, if a page with an AJAX interface is visited and the data on that page is refreshed several times by the AJAX functionality, the back button will take you to the previous page instead of going through the previous data on the same page. Since the back button is fairly intuitively used by users, care must be taken to present a highly visible, alternative solution to the back button functionality, preferably in the form of links that call some javascript function to help retrieving the previous state of the same page.

AJAX applications are also difficult to debug because the processing logic is embedded both in the client and on the server. The client-side JavaScript code may be viewed simply by selecting View Source from an AJAX-enabled HTML page. A poorly designed AJAX-based application could open itself up to hackers or plagiarism.

### 4.8 Error and Exception management

A significant part of the design process of any large software is the handling of errors and exceptions. This section alone deserves a detailed article covering every nuances of its use.
Theoretically, the logic flow in any large process will work correctly for a very small set of data that are "valid". Any one "invalid" data has the potential of disrupting a whole chain of linked processes and workflows. The way exceptions, warnings, errors and fatal errors are handled goes a long way towards distinguishing a great software from a crappy one.

From my experience, exceptions are best handled in as much far in the top level as possible. An user applying for a graduate program may not make anything out of a file open error that is deep inside the system, but a more generic message saying the system has encountered some problem will make much more sense.

A lot of methods in Java's extensive API throw a variety of Exceptions, all of them are subclasses of the most generic class Exception. A few guidelines can lead to a better handling of exceptional cases:

1. **Exception forwarding.** In a series of nested method calls it is more logical to forward an exception to the caller if the callee can’t handle or repair the case. Suppose a function is supposed to open a config file and return its contents. If for some reason it can’t find the file, it will get a FileNotFoundException. Now it can do two things: It can return an empty string if the caller doesn’t bother to know if any error happened. Or it can forward the exception to the caller by throwing it explicitly.

2. **Exception wrapping.** Like exception forwarding but a number of specific exceptions (subclasses of Exception) can be wrapped up in a application specific custom Exception class. For example, instead of throwing a FileNotFoundException or IOException to a caller method, it can be wrapped in a custom exception class GavConfigException and thrown to the caller.

4.9 **Logging**

The common tendency for developers to use console output for debugging as well as feedback can pretty much be termed as "bad habits" in software development. Using printf, cout or System.out.println() can quickly be messy and actually an obstacle for reading an otherwise well written code. One added fact is that when developers try to debug a part of the code, they put arbitrary console output statements that must be removed or commented after the debug is finished. There are quick ways to do this type of enabling and disabling of debug statements, but they are inefficient at best for use in a large scale software.

An industry-wide used solution for this task is logging. Logging involves using an API designed for a multi-tiered approach to outputting a varied levels of messages to a number of configurable destinations. Using the logging infrastructure, turning debug messages on/off alongwith all kinds of change of preferences can be done using a configuration file. Moreover, message output destinations are pluggable, this means we can add a file, a database connection, or even an e-mail to the message output stream. The e-mail plugin is helpful when we are interested in being notified for some critical/fatal errors happening in the system during runtime.

4.9.1 **log4j**

One of the most useful java packages is the log4j API for logging. The startup being a single line at the beginning of a java class and a simple configuration file in the current directory, there is no reason to not use it for the benefits it introduces to software development of any kind.

log4j employs several key concepts: The message severity levels or Priorities, The pluggable message destinations or Appenders and the hierarchical logging sources or Categories. The log messages can be formatted by a format string. Everything above can be configured using a config file.

**Priorities** are several levels of messages, like DEBUG, INFO, ERROR, WARN, FATAL in the increasing order of severity. The basic idea is that a threshold can be set so we can only be interested on messages above a specified priority.

**Appenders** are pluggable destinations. A message can be channeled to multiple destinations that are interested to be notified. For example, we can plug console as well as a file for a
particular category of messages. Each appender can set its own threshold of messages, so we can set the console to show all messages up to DEBUG, while the file only will store messages up to the severity INFO. Each appender can have a different output format too.

*Categories* are like full java class names with package names. Basically a dot separated notion to employ the idea of inheritance. A category *foo.bar* will inherit properties from its parent category *foo*. This is particularly useful when used inside code base that is divided into multiple hierarchies, like we did.

### 4.10 Tools

A number of assistive software tools have been made to help providing a library of useful methods like making connection to database, sending an email and generating code for some parts of the system. Once properly tested, this provides immunity from common typographical errors that can potentially slow down the dev-test cycle.

#### 4.10.1 EmailHelper

This is basically an email tool to send out email. During out dev-test cycle we have used the free POP/SMTP service of softhome.net till now. Currently we use a gmail account as the previous one stopped their free service. To use the SMTP service of gmail, other than using the port 465, we needed to specify a few more properties to enable sending mail using TLS. They are as follows:

```java
props.put("mail.smtp.starttls.enable", "true");
props.put("mail.smtp.socketFactory.port", "465");
props.put("mail.smtp.socketFactory.class", "javax.net.ssl.SSLSocketFactory");
props.put("mail.smtp.socketFactory.fallback", "false");
```

#### 4.10.2 BeanHelper

While we wanted the manager classes would be generated from specifications, it was going to involve a rigorous tool that would have taken a lot of time. All the managers use a fair amount of code that involve getting/setting bean variables, retrieving parameters from http request and so on.

The BeanHelper tool outputs a series of code fragments that are supposed to be copy-pasted in various parts of the manager code. The output consists of multiple formats that concerns different parts of the functions in the manager class.

#### 4.10.3 TableConv

It is always desirable to have an isolated testing environment of a web-application, including a separate database space. The real database where the data from a production version of the web application will actually go is an important one and can’t be offered as a testing ground over the duration of the development. This necessitates a tool which can operate as a bridge between the application-specific database and the global database and can be used in a caching-like mechanism. Whenever there is a pool of new data collected in a session with the web application, the tool can dump them together to the global database in one go.

The table converter tool basically maps fields from one table to another, and it can be configured such that inter database table mapping becomes possible.
5 Efficiency

5.1 Code redundancy reduction

Code redundancy is by far the most unwanted and ill aspect in any large code base. Often developers opt for a quick fix at some part of code by borrowing code from another part which is essentially a replica of a code fragment. This kind of quick code-fix is nothing but a vulnerable place for a bug if one of those two replicas is later found to contain a bug and is fixed while the other place is forgotten.

To handle this problem, code re-use is one of the most important approaches according to best practices of software development. A replicable code can be made as a function and placed at a convenient place like a library and can be called from as many places without the risk of having stale code. Obviously re-use is a valid way to deal with the situation where we need exactly same code in more than one place, but doesn’t concern using similar but not identical codes. In most cases we face the problem of having to copy a chunk of code from another place and change a few variable names, leaving the logic same as before. This is another significant form of avoidable redundancy, because if the logic changes later in one place it has to be changed manually in other places with different variables.

In our approach we attack the problem of similar code redundancy by generating code that are functionally similar. As a concrete example, we are generating the java beans which are basically a container with a set of variables and getter/setter methods for those variables. Once we know the bean class name and the variable names, the rest is pretty much mechanical, except a few places to fine tune. Generation of those beans from a simple specification and a custom tool saved a lot of time hand-coding them. Furthermore, since the beans depend on the database tables, with each minor change in a table the regeneration of a compilable bean class becomes a breeze.

We also discuss another probable speedup in our web-application development, after spending hours on hand-coding the jsp pages. As we discovered an approximate pattern, though much more complex than the beans, a specification for a jsp form page can be written and the forms generated much like the beans with our ability to fine tune for the looks and other stuff related to the "View" component of the MVC model.

5.1.1 Form generation - an approach

A form page can be simply viewed as an interface to insert or update a table row or a part of it. In most cases, the fields in a form exactly corresponds to the fields in a database table. Besides the jsp form pages are basically a function of a few parameters like the table name, fields, the action servlet and so on.

It would be a logical approach to generate form pages based on a table schema. The key challenges involved are the types of the fields and the proper interfaces to present the data. A typical example of this is the choice of using radio buttons or a checkbox for a boolean field. This task can be best handled by a well formed specification language and a custom tool to generate a form from the specification.

5.1.2 AppFuse

AppFuse is a very radical approach to web-application development by Matt Raible. Given a database schema, it generates the bulk of the common CRUD (Create, Retrieve, Update, Delete) code, which can be customized for individual use. It extensively uses new technologies in every tier, and a drawback of using it is the need of in-depth knowledge of all the components, mainly the Spring/Struts MVC model and the Hibernate database abstraction layer.

Appfuse has a great potential to help with this scale of web-application development, but needs intensive training to master the fairly complex frameworks.
6 Security issues

Like many standalone softwares are prone to attacks like buffer overflows and format string exploitations, web applications have their own set of vulnerabilities. In this section we will discuss a few of them and how much protection our system has from them.

6.1 SQL injection

This is a common vulnerability of a web-application. When the server side code communicated with a database by an SQL query using a parameter sent by client in a query string, SQL injection is possible. For example, if the client is supposed to send a "name" parameter to server and the server makes the following query:

"SELECT * from login where name = " + name

where the variable name will have the client supplied data. An injected malicious data can be something like:

'john'; UPDATE login SET root_access = 'Y' WHERE name = 'john'

This will actually make two statements which upon execution give some authoritative access to the user john.

However, this injection works in php as a research paper suggests, but as soon as the java code sees the semicolon separating two SQL statements, it throws up an exception. JDBC doesn't allow executing two statements like this, hence our system is secure from this exploit.

6.2 Directory traversal

In a directory traversal attack, an attacker attempts to access files outside of an authorized directory, e.g., the document root in the case of a web server. This is usually done by including ".." to ascend above the document root. If there is a check for "..", they can use hexadecimal representations of the characters.

However this attack is more suitable on a ftp server than a tomcat server that we are using. Tomcat wont let us using ".." maliciously and it can only result in showing upto Tomcat's home page.

6.3 XSS: Cross Site Scripting

Cross site scripting (also known as XSS) occurs when a web application gathers malicious data from a user. The data is usually gathered in the form of a hyperlink which contains malicious content within it. Usually the malicious portion is encoded in hex so it looks less suspicious.

Common places to find XSS are large websites and bulletin boards. Some XSS can automatically execute when opening email or attachments or even just reading a public guestbook or forum post. One of the best ways to avoid any harm from these is to turn off javascript.

6.4 Does SSL actually offer protection?

Websites that use SSL (https) are in no way more protected than websites that are not encrypted. The web applications work the same way as before, except the attack is taking place in an encrypted connection. People often think that because they see the lock on their browser it means everything is secure. This just isn’t the case.
6.5 Secure payment using Verisign

We used Verisign, a proven, secure third party online payment system for the credit card payments. We pass the userId and when the transaction is approved we do a silent post and after the submit we return to the original page. In this way we don’t lose any transaction even if the user closes the window when he gets the receipt from verisign. Since at the beginning of the transaction we pass the user ID, on the return from the transaction we save the activation number for the user. In this way the processing of the credit card is passed to a secure specialized website and there won’t be any information about the credit card saved on our side.

7 Special security issue: XSS

The cross-site scripting attack is one of the most common yet overlooked problems that web developers face today. Cross-site scripting works by embedding malicious code on web pages with tiny "scripting" programs usually embedded in a hyperlink. When an unsuspecting visitor clicks that link it activates the hacker’s program by using the corrupted script. Once activated, the rogue program allows the hacker to slip undetected past firewalls to read steal information from cookies, credit card numbers and other data.

7.1 Who is at risk

Mainly dynamic web sites are at risk from this type of attacks. Static sites should be free of concerns. Dynamic web sites like online forums face this risk because of their capability to generate pages on the fly based on unvalidated input, like when some random user posts a hyperlink crafter with malicious script content.

Even having an SSL-enabled website is not a cure from XSS. The attacks work the same way as before, only in an encrypted connection in the case of SSL.

Any poorly coded script is a potential target because they sit on the boundary of outside data and the server and usually has the ability to execute commands powerful enough to do damage to the system. If the script isn’t careful about what data it is processing it could be hijacked by some clever scripting data, leading to disaster.

7.2 Mechanism

Most web browsers can interpret scripts embedded in web pages. For example, with \texttt{iframe}, tags, a script will be executed upon just viewing the page. Such scripts may be written in a variety of scripting languages and are run by the client’s browser. Most browsers are installed to run scripts enabled by default.

The malicious code embedded in a hyperlink can be encoded as hex to make it look less suspicious.

Malicious code provided by one client for another client

Sites that host discussion groups with web interfaces have long guarded against a vulnerability where one user embeds malicious HTML tags in a message intended for another user. For example, an attacker might post a message like

\begin{verbatim}
Hello, Start of message.
<SCRIPT>malicious code</SCRIPT>
End of message.
\end{verbatim}

When a victim with scripts enabled in their browser reads this message, the malicious code may be executed unexpectedly. Scripting tags that can be embedded like \texttt{<SCRIPT>}, \texttt{<OBJECT>}, \texttt{<APPLET>}, and \texttt{<EMBED>}.
Most discussion group servers either will not accept such input or will encode/filter it before sending anything to other users.

**Malicious code sent inadvertently by a client for itself**

A situation may occur when the client relies on an untrusted source of information when submitting a request. For example, an attacker may construct a malicious link such as

```
<A HREF="http://example.com/comment.cgi?mycomment=<SCRIPT>malicious code</SCRIPT>"> Click here</A>
```

When an unsuspecting user clicks on this link, the URL sent to example.com includes the malicious code. If the web server sends a page back to the user including the value of mycomment, the malicious code may be executed unexpectedly on the user’s computer. This example also applies to untrusted links followed in email or newsgroup messages.

A simple example of cookie theft is given below:

```
\protect\vrule width0pt\protect\href{http://www.example.com/search.pl?text=<script}{http://www.example.com/search.pl?text=<script>
```

If an attacker can get us to select a link like this, and the web application does not validate input, then our browser will pop up an alert showing our current set of cookies. This particular example is harmless but an attacker can do much more damage, including stealing passwords, resetting home page, or redirecting to another website.

Even worse is the case of `<IFRAME>` tags. Scripts inside that can run by just viewing the page.

XSS holes allow Javascript injection, which may allow limited command execution. If there are browser holes as well, commands can be executed on the client’s side as well. So XSS holes can be used to possibly exploit browser holes as well.

### 7.3 Ways to prevent

The easiest way of protection is to avoid clicking on links posted by arbitrary users on a web forum. Sometimes XSS can execute automatically upon opening email or reading a forum post. Some caution can be exercised in these cases by turning off Javascript in the browser settings. This can prevent cookie theft too.

One of the ways to thwart XSS is to sanitize the input data which comes when some innocent user clicks a carefully crafted hyperlink made by a hacker. For example this data can come through the $QUERY_STRING variable in the context of CGI programs. Most of the time the culprit are `<script>` tags and javascript function calls, so removing the characters ‘<’, ‘>’, ‘(’, ‘)’ should be a good first step. But, instead of removing bad characters, a better and recommended approach is to define a list of acceptable characters and replace any character not in the list by an underscore. In that way the programmer becomes certain that whatever string is returned, it contains only characters under his/her control.

A basic perl code for this should look like:

```
#!/usr/local/bin/perl
$_ = $user_data = $ENV{'QUERY_STRING'}; # Get the data
print "$_
";
$OK_CHARS='^a-zA-Z0-9._@'; # A restrictive list, which
# should be modified to match
# an appropriate RFC, for example.
s/[^$OK_CHARS]/_/go;
$user_data = $_;
print "$_
";
exit(0);
```
In our web application, special checking for every user input needs to be done. We use POST mechanism to submit form information to server. In the backend, the servlets are coded to make any GET request also handled the same way as POST. We can disable any use of GET mechanism, but still some attacker might craft a malicious script in one of the textfields as user data when filling up a form. As a possible solution, during the field validations, all the fields must go through a sanity check function before other data validation should take place. A warning can be issued if the user data contains unacceptable characters like mentioned in the previous paragraph.

8 Concurrency issues

Concurrency refers to the sharing of resources by multiple interactive users or application programs at the same time. When developing such an application, care should be taken to prevent undesirable effects, such as:

- **Lost updates.** Two applications, A and B, might both read the same row from the database and both calculate new values for one of its columns based on the data these applications read. If A updates the row with its new value and B then also updates the row, the update performed by A is lost.

- **Access to uncommitted data.** Application A might update a value in the database, and application B might read that value before it was committed. Then, if the value of A is not later committed, but backed out, the calculations performed by B are based on uncommitted (and presumably invalid) data.

- **Non-repeatable reads.** Some applications involve the following sequence of events: application A reads a row from the database, then goes on to process other SQL requests. Meanwhile, application B either modifies or deletes the row and commits the change. Later, if application A attempts to read the original row again, it receives the modified row or discovers that the original row has been deleted.

- **Phantom reads.** The phantom read phenomenon occurs when:
  1. Application A executes a query.
  2. Another application B inserts or updates data that satisfies A’s query criteria.
  3. Application A repeats the query from step 1 (within the same unit of work), but the result set is different because it includes additional ”phantom” rows inserted or updated by application B.

Such concurrency issues can be prevented in the application by managing locks and isolation levels. If the application does not require multiple database connections, then we can avoid concurrency issues altogether by disabling shared access. For example, the connect() method in the java.sql.Driver interface supports ENABLE_SHARED_DATABASE_ACCESS, a boolean property that can be set to false to disable concurrent access.

Since our application is going to handle sufficiently low volume of user interactions, we can safely turn off the above key. The ENABLE_SHARED_DATABASE_ACCESS key is set to false by default hence our system is free from the concurrency issues.

9 Performance

After developing any software it is customary to evaluate its performance. Often a standardized method called benchmarking is used to test a software and also to compare its performance with other similar products in market. Regression tests measure the worst case performance.

A web application is unlike a standalone software in the area of testing. Test suites can be written for a standalone software to quickly and repetitively test individual methods or a sequence of operations expected in normal use. Web applications require client inputs through
is about the limit for having the user feel that the system is reacting instantaneously, meaning that no special feedback is necessary except to display the result.

1.0 second is about the limit for the user’s flow of thought to stay uninterrupted, even though the user will notice the delay. Normally, no special feedback is necessary during delays of more than 0.1 but less than 1.0 second, but the user does lose the feeling of operating directly on the data.

10.0 seconds is about the limit for keeping the user’s attention focused on the dialogue. For longer delays, users will want to perform other tasks while waiting for the computer to finish, so they should be given feedback indicating when the computer expects to be done. Feedback during the delay is especially important if the response time is likely to be highly variable, since users will then not know what to expect.

| 0.1 second | is about the limit for having the user feel that the system is reacting instantaneously, meaning that no special feedback is necessary except to display the result. |
|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.0 second | is about the limit for the user’s flow of thought to stay uninterrupted, even though the user will notice the delay. Normally, no special feedback is necessary during delays of more than 0.1 but less than 1.0 second, but the user does lose the feeling of operating directly on the data. |
| 10.0 seconds | is about the limit for keeping the user’s attention focused on the dialogue. For longer delays, users will want to perform other tasks while waiting for the computer to finish, so they should be given feedback indicating when the computer expects to be done. Feedback during the delay is especially important if the response time is likely to be highly variable, since users will then not know what to expect. |

Table 1: Acceptable UI response times

interactions in web pages and is much slower to test. For every test case the client has to click a series of buttons and fill up forms in a particular order.

A basic UI performance test is the measure of response time of form actions within an acceptable time frame. Table 1 summarizes the acceptable response times for any UI application.

Even though our system is not tested on a production machine, it performed pretty much according to the above table. The worst case time it takes for a page to load is a few seconds when it loads a drop down list of all academic programs available in the university, which is pretty huge.

Due to time and resource crunch, we could not perform regression test on the system. But since this is not a web application which many users will use often, simultaneously and repetitively like a typical financial or dating portal, we can estimate that our system should behave normally under normal use and circumstances.

10 Future improvements

Like in any software development process, a few things were learnt in the later stages of growth of our web application. Lack of time and resources prevented us from getting the best out of the learning, but if properly documented, it might help someone to easily implement it in future.

10.1 Role-based access control (RBAC)

Initially our system started with only the student applicants in mind. Our resources were spent making a well designed web application but with little focus on the future growth in terms of different classes of users and their varied forms of accesses. As the application is going to deal with personal and possibly confidential data about prospective students, it is highly important to have a proper access control mechanism in place.

Role-based access control seems to be a fair candidate in this situation. A multitude of roles can be configured and tuned for the right access control. Users can just be assigned a role, and when the access for a role needs to change, the necessary access modifications can take place in only one location, instead of all the affected users.
10.2 Form field validation using custom tags

Even our systematic approach towards server side validation using the beans as container of validation logic seems laborious. In the frameworks like struts, custom tag libraries for common field validations can be used for much easier development workflow. Custom validation logic can be specified in an XML document, removing the necessity to recompile java code for every modification.

11 Using CVS and parallel development

For projects of this scale, version control should be a mandatory practice. Not only does it ensure good collaboration between multiple developers, having the repository residing on a stable servers removes a lot of vulnerability of carrying the code in personal laptops. Besides, it becomes extremely easy to work from anywhere and not to worry about working on the latest version of the code.

Parallel development on different parts of our project has been possible and highly beneficial on account of the MVC model we employed. Using CVS allowed us to quickly combine each other’s code updates of various parts. This greatly reduced the typical use of email and other means even for sharing temporary trial codes.

12 Conclusions

A robust web application should employ the same principles of developing quality softwares. Only the tools and frameworks differ between the two. Techniques will always largely depend upon what kind of commitment the developers can put in the effort, as it will different for fulltime developers working in a company and students with a finite number of semesters in school.

There are many scopes of improvement over our design, each with its pitfalls, but a good initial design can take care of most issues. AJAX can be used from the beginning as it is increasingly becoming the standard in producing web applications that behave like a standalone application. Its few pitfalls can be easily overcome with a carefully designed workflow from the scratch.

With the advent of new frameworks, making a robust web application that would run for a few years without getting too much outdated is a challenging issue. Existing frameworks for making large scale web application are not only huge but needs a lot of training to maintain and add features. A basic framework using java beans and servlets is still a good solution for a medium scale application like this and at the cost of less sophistication, it is rather easy to be maintained by students.
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Appendix A

Usage of tools

The usage of the custom tools to generate code is given below:

**BeanHelper**

Usage: `java BeanHelper table_a field_aa field_bb ... field_nn`

This will generate the following code fragments:

```java
-------------- SETTERS -------------
b.setFieldAa(rs.getString("field_aa"));
...
```

```java
-------------- ADDERS -------------
String insertStmt = "INSERT INTO table_a(field_aa, ..., field_nn) VALUES ( xxxID.nextval, + "," + b.getFieldAa() + "', "," + b.getFieldBb(rs.getString("field_nn"));
...
```

```java
-------------- UPDATERS -------------
String updateStmt = "UPDATE table_a SET " + "," + b.getFieldAa() + "', "," + b.getFieldBb(rs.getString("field_nn"));
...
```

```java
-------------- TESTER -------------
TableAManager = TableAManager.instance();
TableABean b = new TableABean();
b.setFieldAa("field_aa1");
...
```

```java
-------------- HELPER for servlets ---------
String fieldAa = request.getParameter("fieldAa");
...
```

**TableConv**

Usage: `java TableConv <spec_file>`

The spec_file contains table conversion specification as follows: The first line contains source and destination table names separated by a whitespace. The following lines contain one source field and corresponding destination field separated by a whitespace, till a blank like. Multiple such specifications can be put in a single specification file. An example is:

```bash
language ps_su_apply_language
language_id SEQNUM
user_id SU_APPLY_USER_ID
language_name LANGUAGE_CD
speak READ_PROFICIENCY
read WRITE_PROFICIENCY
write SPEAK_PROFICIENCY
```