Java Security Vulnerabilities Detection With Static Analysis

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Abstract:

Security in software plays an important role in todays society as computer networking is getting more and more important. Security measures are taken to protect private information, but bad programming practices can still cause security vulnerabilities in software systems. Source code analysis tools can be used to detect such security vulnerabilities automatically. The use of these tools helps to improve the quality and security of software systems and could prevent future problems.

The class of security vulnerabilities called input validation vulnerabilities can be detected using static taint analysis. The design and implementation of such a tool are the subject of this paper. This tool detects input validation vulnerabilities in source code written in the Java programming language. This paper also describes in detail how to deal with complexities related to the object oriented nature of Java.

The tool first derives a graph structured model from the source code. This graph structured model captures data dependency relations between important program elements. This graph model is then analyzed using taint analysis to detect potential input validation vulnerabilities.

Keywords:

SQL Injection, Software Analysis Toolkit (SAT), Cross site scripting (XSS).

I. INTRODUCTION:

In today's world where computer networking plays an important role in everyday life, computer criminals cause havoc in critical or important network environments. Com- mon criminal activities include: tapping network traffic, tampering databases, modify- ing websites, disabling services and information theft [26]. These activities can cause bad publicity, data-loss and privacy problems, which could result in significant (financial) damages to companies.

Systems that are secure enough to resist such attacks are therefore essential. Security breaches are often the result of bad programming practices during development.Some of these security vulnerabilities are easily detected and fixed when the program crashes or unexpected output is given. Other security vulnerabilities will never be noticed during normal use. Automatic source code analyzers can help detect- ing these security vulnerabilities before deployment of a software system.

1.1. Style Conventions:

This paper follows a style convention for clarity. The following style conventions are used:

• Relevant large program parts are displayed as code fragments, which are listed on its own index page. The code of a simple class is given in code fragment 1.1. The keywords that belong to the programming language are bold. The lines are numbered for easy referencing in from the text.

1.2. Development Environment:

To get an impression of how the security tool is developed at the office of the Software Improvement Group (SIG), the development environment is described. To confirm to the existing software standard used by SIG, the development environment influences the way the tool is developed. The workstation is an Apple iMac running Mac OS X as Operating System, which is also connected to the Internet.

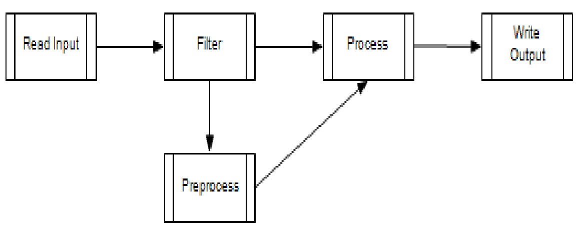


Figure 1.1: Flow diagram

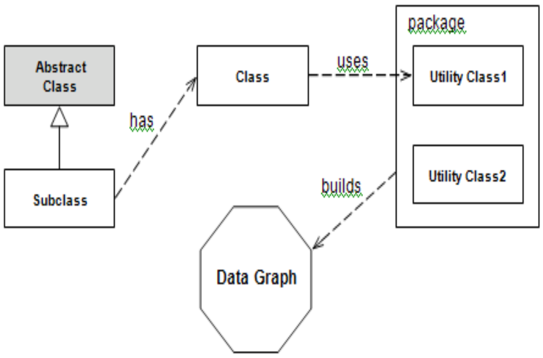


Figure 1.2: Modules diagram.

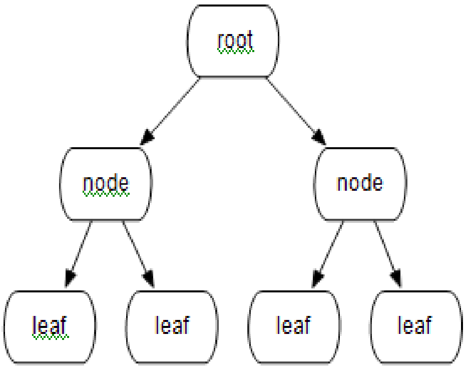


Figure 1.3: Graph diagram.

II. JAVA SECURITY VULNERABILITIES:

2.1 SQL Injection:

A popular application of the Java programming language is the use of Java servlets to handle web server requests. The underlying pattern in the architecture of a potential vulnerable system is depicted below in figure 3.1 as an example. The architecture consists of three modules or components, which are interacting with each other.

The web server component is responsible for handling requests initiated by the user. When a HTTP request is received from the user, the web server delegates the request to the Java servlet. The Java servlet may interact with a SQL database by querying, which depends on the user input. In short, a system may be vulnerable to SQL injection attacks, when SQL input by an application depends on the user input.

SQL injection [43, 31, 32, 13, 19, 38] occurs when the semantics of a SQL query that is embedded in the source code is changed due to specially crafted user input. The bad query can do things not allowed or intended by the application. The syntax of the embedded may be correct, but the semantics is changed.

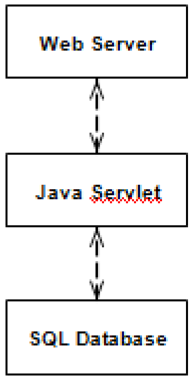


Figure 2.1: Web server Java SQL architecture.

2.2 Cross Site Scripting:

In cross site scripting (XSS) [43, 31, 32, 19, 38] a vulnerability exists in a web ap- plication that makes it possible to trick users of the website to execute arbitrary code using the website as a relay. The code appears to be originated from the website that may be a website that is trusted by the users. The trust of the user in a website with a XSS vulnerability and the website itself are abused to trick the computer/browser of the user to execute arbitrary code, which steals private information from the user. No entry is gained in the website itself.

The attacker who wants to abuse an XSS vulnerable website, first crafts a special hyperlink that has hidden code embedded. The code is meant to steal information from the user. The second problem is to get the user to click on this link. One way to do it is to post it on a forum that is known to be regularly visited by users of the XSS vulner- able website, another way is to email it directly to the users. If an user has clicked on the link, the code in the link is relayed and echoed back to the user by the website. The browser of the user starts executing the code, which can do things like stealing cookie information that contains login information. Stealing cookie information can be done by letting the code dump this information at a specially installed drop site.

2.3 Command Injection:

Command Injection [43, 31, 32, 38] tricks the application into executing another pro- gram. This can be used by an outsider to gain entry into a web server or to execute something with the same privileges as the application. It can also be used by an user of a stripped down computer. A stripped down computer is intentionally restricted in accessibility, so the only use of the computer is through a particular program or interface.

2.4 Input Validation Vulnerabilities Detection:

SQL injection, cross site scripting, command injection and path traversal vulnerabil- ities have fundamental properties in common. The commonality is that user input is trusted and not validated before it is used in a subsystem. A subsystem is an in- dependent system that is used by the application. This subsystem is accessed by its interface, which is commonly a collection of methods. The subsystems of the vulner- able programs discussed earlier, are the SQL database for applications vulnerable to SQL injections, the browser for cross site scripting vulnerable websites and the un- derlying operating system for the last two vulnerabilities. These vulnerabilities would not exist if user input is properly checked and sanitized before being used, eliminating dangerous input. The vulnerability is exploited when the attacker tricks the subsystem into doing something not intended by the application.

III. SOFTWARE ANALYSIS TOOLKIT (SAT):

This section describes the Software Analysis Toolkit (SAT) framework used by the SIG to perform Software Risk Assessments (SRAs). The SAT is a collection of software analysis programs used to analyze all kinds of software systems. Each program does so by looking at the source code of the system, which is better known as static analysis. Implementing a new analysis for the SAT requires the use of standard classes and inter- faces provided by the SAT software framework. SAT makes it possible to perform the analysis in a standardized way and it prevents source code duplication. The standard classes that are described below form the basis of SAT. To understand the existence of these classes and why they are standardized, a typical source code analysis will be described.

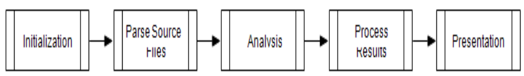
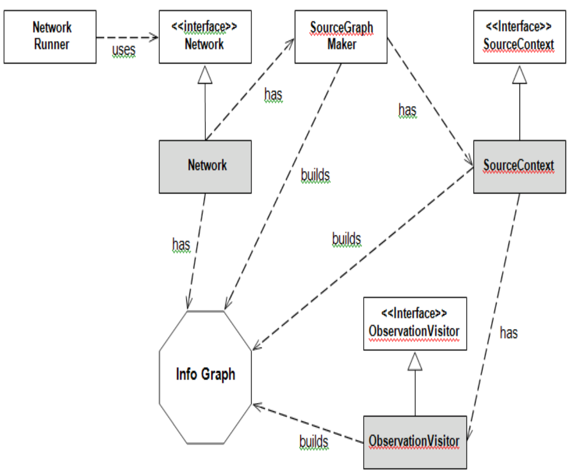


Figure 3.1: Simple analysis.



IV. JAVA SECURITY ANALYSIS:

4.1 The Security Analysis Architecture:

The architecture of the Java Security Analysis is illustrated in figure 8.1. Interface classes and several other supertypes that belong to the SAT framework are omitted to avoid cluttering in the figure. The architecture includes the classes discussed in earlier chapters. The heart of the architecture is the Security Fact Graph, which role is twofold. First, the graph is constructed while the Java source files are analyzed. Second, the graph is analyzed to dectect input validation vulnerabilities.

The Java classes in the Java Security Analysis are divided into Java packages. Related classes belong to the same package, often packages contain classes that inherit from the same superclass. There are 5 packages in total.

• typeinformation: This package contains classes that are used to resolve pro- gram entities like (super) classes, variables and methods.

• obsvisitors: This package contains subclasses of the ObservationVisitors class, which are used to traverse source files. An AST is constructed for every source file, which is then analyzed by using the TreeWalker class.

• astvisitors: This package contains subclasses of the AbstractActionVisitor class, which are used by the TreeWalker class to traverse the ASTs.

• sfgvisitors: This package contains subclasses of the AbstractLinkVisitor class, which are used to traverse the Security Fact Graph.

• javasecurityanalysis: This package contains all other classes.

4.2 Experimental Results:

A guestbook web application is created to show the workings of the analysis on a real Java web application. The source code of the guestbook can be found in ap- pendix D. The guestbook has two basic functionalities.

One is adding a new guest- book entry to the database and the other is retrieving all the entries from the database for display. A MySQL [49] database is used to store guestbook entries. The guest- book contains several SQL injection vulnerabilities.

The untrusted method is speci- fied as javax.servlet. ServletRequest.getParameter(), which returns the user supplied parameter. In order to make the security vulnerability complete, the criti- cal method java. sql.Statement.executeQuery() is used, which executes a SQL query..

The stripped Security Fact Graph that corresponds to the guestbook can be found in figure 8.2. All the nodes of the stripped Security Fact Graph are tainted. Redundant nodes are removed, without influencing the outcome of the analysis. The names of the edges are not displayed. Like expected, several dangerous paths from an untrusted method to a critical method are found. In total, there are three paths found. The paths originate from the getParameter() method call, which is used to retrieve the user input. The paths end with the executeQuery() method call on the Statement object. The specific tainted paths can be found in appendix E, which contains the literal output file content.

The analysis does not recognize methods or algorithms used to validate input, which means that dangerous tainted paths are also found if the input is validated cor- rectly. This is the reason why tainted paths found by the Java Security Analysis have to be verified manually.

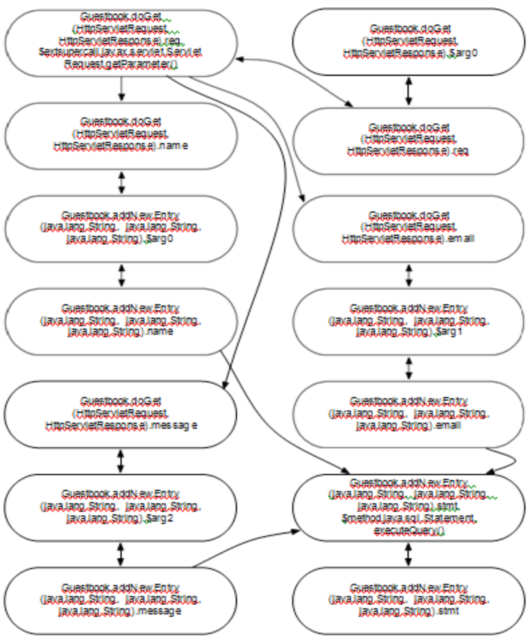


Figure 4.1: Security Fact Graph of Guestbook

CONCLUSION:

The Java Security Analysis allows SIG to detect security vulnerabilities in software of clients. The list of services to clients can be extended by a security check or assessment service, which makes it interesting for clients who want their Java web application to be checked for security vulnerabilities. The other contributions are actually side products, which are essential components of the analysis. The first one is the extended type inference framework, which now supports object types. This is in contrast with the former type inference framework, which can only deal with integer types. The second is the BCEL wrapper that is used to resolve library types. This wrapper is proven to be useful and it can be used to increase accuracy of the existing analyses used by SIG.

The analysis is strongly data flow oriented, which means that it can easily be mod- ified for other purposes than detecting security vulnerabilities, for instance, to identify all locations where a certain value is used. This way, dependencies of classes or mod- ules on that value can be identified to separate software architecture modules. This information can be used to improve program understanding, which is in line with the SWERL research area.

This project shows a way how type inference can be used to capture data depen- dency relationships between variables. These relationships are then used to perform taint analysis in order to detect input validation vulnerabilities. It also shows a way to deal with objects, which can be defined in libraries. In addition to normal source code analysis, the use of byte code analysis is described to improve accuracy.

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