Defensive programming

What is it

- An approach to improve software and source code, in terms of:
  - general quality, reducing bugs
  - Making it comprehensible, or understandable
  - Predictable behavior against unexpected inputs or user actions

Rules of defensive programming

- Rule 1: Never assume anything
- Rule 2: Use standards
- Rule 3: Code simple

Rule 1: Never Assume Anything

Rule 1: Never Assume Anything

Rule 2: Use Standards

Rule 3: Code Simple

Error handling in Java EE

Type annotation

Checker Framework

Application-layer security

Transport-layer security

Message-layer security

Secure connection with SSL

Input Validation

- User's input and actions are not trustable
- All input and actions must be validated
- Handle exceptions:
- Terminate
- Retry
- Warning

Example

- Imagine a bank transaction and answer these questions:
- What kind of variable you need? int, float, string, etc
- Is it going to be a large or small number?
- Can it be a negative number?
- and other questions

Testing Strategy

- Don't limit you testing process to "it works"
- Test error cases
- Test for the illogical input
- Strange ASCII character
- Rolling head
- Ask others to test the application if possible

Order of Precedence

- Is the set order that statements are resolved
- Sometimes it's difficult to see errors in the order of precedence
- `if(InVar=getc(input)!=EOF)`
- When in doubt, use proper parenthesis

Size of Variables

- Some primitive data types on different OSs or hardware platforms have different values
- You should consider the siza of variables when coding

Rule 2: Use Standards

Rule 1: Never Assume Anything

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Coding Standard

- Makes code coherent and easy to understand
- Debugging gets easier
- Wide range of topics
- Variable naming
- Indentation
- Position of brackets
- Content of header files
- Function declaration
- And many more

Variable Naming: Hungarian Notation

- Is a Naming standard
- Starts with one or more lower-case letters that are mnemonics for the type or purpose of the variable:
- iAge: integer type age
- szName: zero-terminated name string

Numbers

- Do not use constant values in the code
- Difficult to understand
- Difficult to maintain
- example: `int Fr = (4.3/1.25)*N;`
- Use constant variable instead
- `cons int PI = 3.1415`
- `int Surface = PI * r * r;`

Rule 3: Code Simple

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Contract

- See functions as a contract
- Given input, the execute a specific task
- They should not able to do anything else rather than the specified task
- Exception handling

Refactoring

- Is a technique for restructuring the code, changing its internal structure whithout any change in external behavior
- Does not fix the bugs
- Can be used for battling feature creep:
- Added features during coding
- Usually cause problems
- Keeps your application simple

Third-Party Libraries

- Code reuse a safe choice
- More stable and secure than what you make in a limited time

Error handling in Java EE

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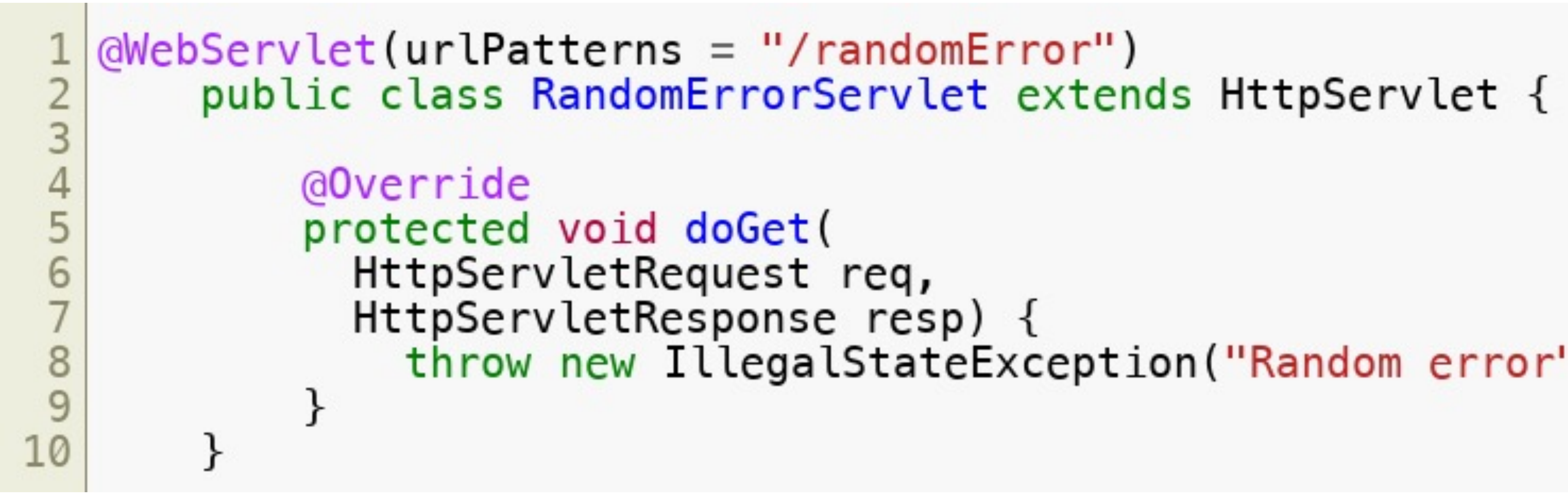
A servlet structure

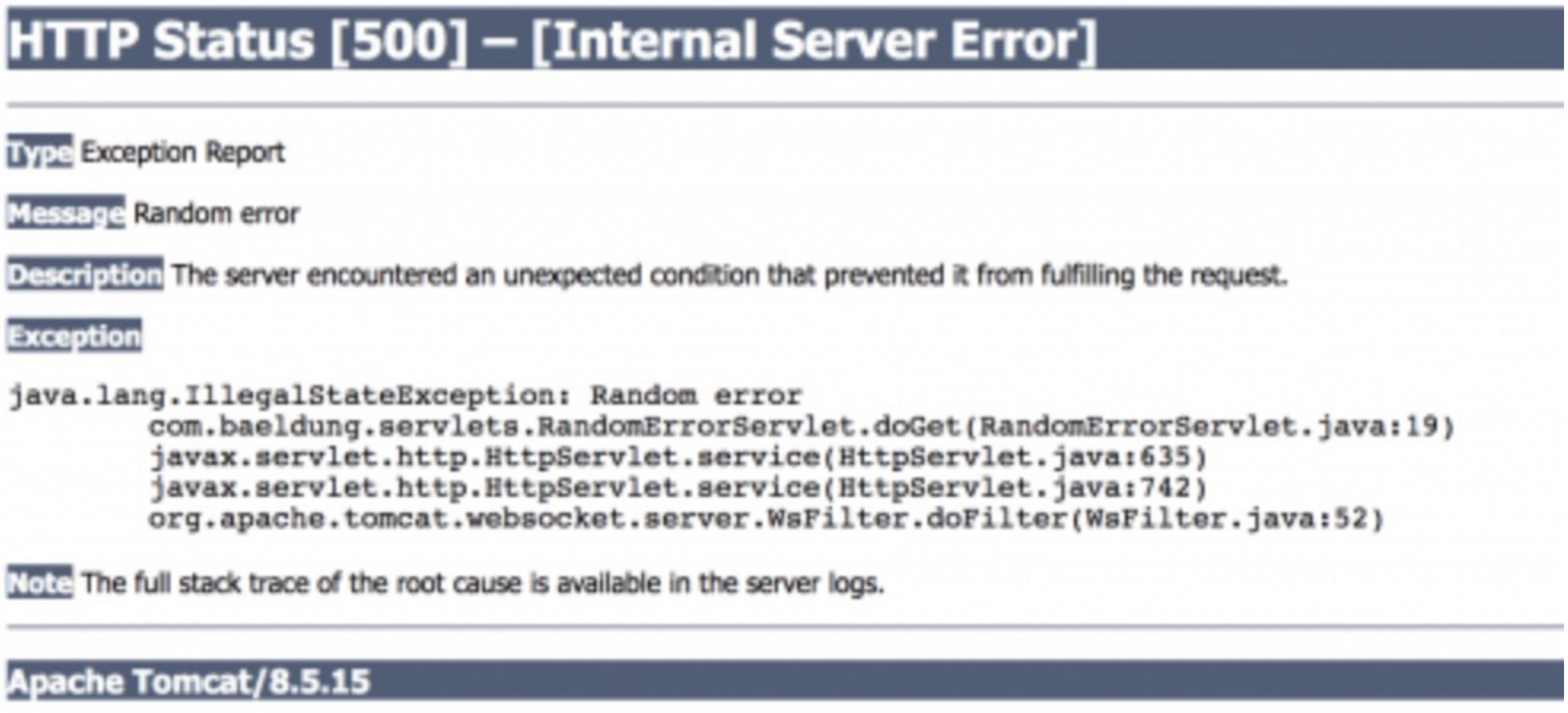


```java
@WebServlet(urlPatterns = "/randomError")
    public class RandomErrorServlet extends HttpServlet {

        @Override
        protected void doGet(
          HttpServletRequest req,
          HttpServletResponse resp) {
            throw new IllegalStateException("Random error"
        }
    }
```

Default Error Handling

- Let us deploy our servlet here
  - http://localhost:8080/javax-servlets
- Now, let us look at the error here
  - http://localhost:8080/javax-servlets/randomError
- What happens? We see the generic error



HTTP Status [500] – [Internal Server Error]

Type Exception Report

Message Random error

Description The server encountered an unexpected condition that prevented it from fulfilling the request.

Exception

```
java.lang.IllegalStateException: Random error
	com.baeldung.servlets.RandomErrorServlet.doGet(RandomErrorServlet.java:19)
	javax.servlet.http.HttpServlet.service(HttpServlet.java:635)
	javax.servlet.http.HttpServlet.service(HttpServlet.java:742)
	org.apache.tomcat.websocket.server.WsFilter.doFilter(WsFilter.java:52)
```

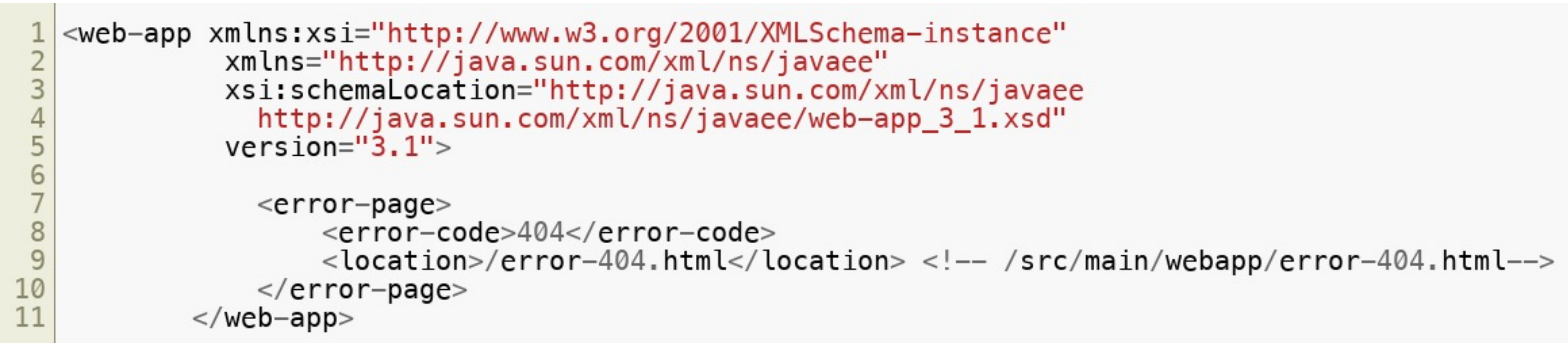
Note The full stack trace of the root cause is available in the server logs.

Apache Tomcat/8.5.15

Custom Error Handling

- Custom error handling
  - Goes into web.xml file descriptor
- Status code error handling
  - map HTTP error codes (client and server) to
    - a static HTML error page or
    - an error handling servlet
- Exception type error handling
  - map exception types to
    - static HTML error pages or
    - an error handling servlet

With an HTML Page

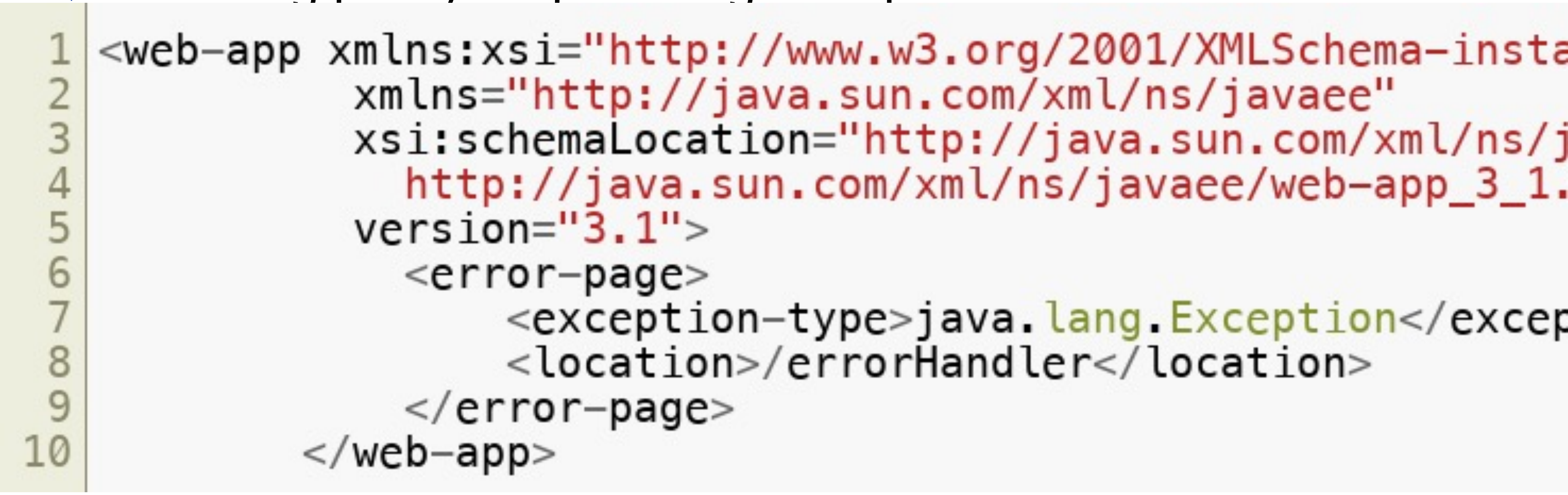


```
<web-app xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
          xmlns="http://java.sun.com/xml/ns/javaee"
          xsi:schemaLocation="http://java.sun.com/xml/ns/javaee
            http://java.sun.com/xml/ns/javaee/web-app_3_1.xsd"
          version="3.1">

            <error-page>
                <error-code>404</error-code>
                <location>/error-404.html</location> <!-- /src/main/webapp/error-404.html-->
            </error-page>
        </web-app>
```

With a Servlet

- Handling policy for java.lang.Exception



```
<web-app xmlns:xsi="http://www.w3.org/2001/XMLSchema-insta
          xmlns="http://java.sun.com/xml/ns/javaee"
          xsi:schemaLocation="http://java.sun.com/xml/ns/j
            http://java.sun.com/xml/ns/javaee/web-app_3_1.
          version="3.1">
            <error-page>
                <exception-type>java.lang.Exception</excep
                <location>/errorHandler</location>
            </error-page>
        </web-app>
```

Type annotation

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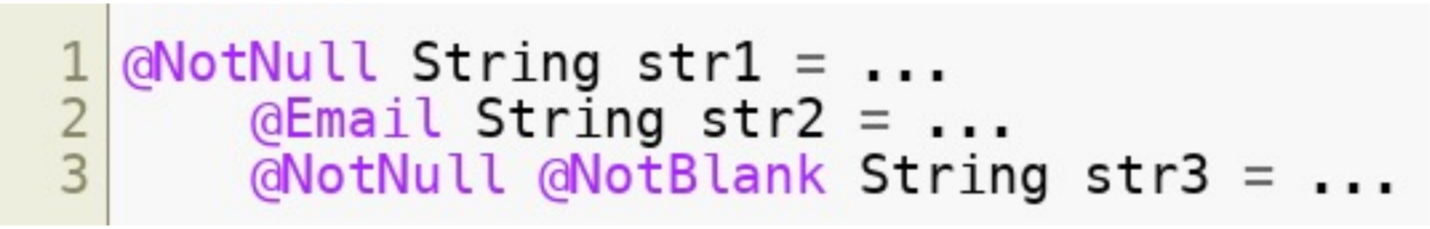
Type Annotations

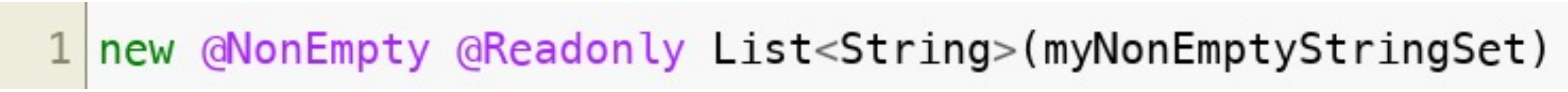
- Annotations that can be placed anywhere you use a type
  - the new operator
  - type casts
  - implements clauses
  - throws clauses
- Benefits
  - Improved analysis of Java
  - Stronger type checking

Simple Type Annotations Examples



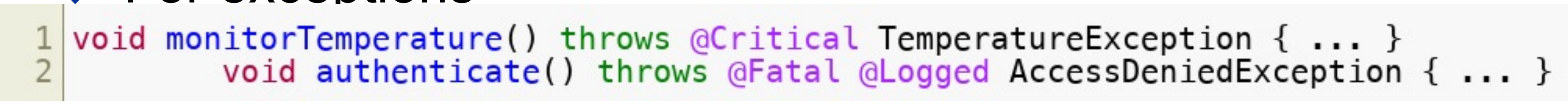
```
@NotNull String str1 = ...
    @Email String str2 = ...
    @NotNull @NotBlank String str3 = ...
```

- With constructors



```
new @NonEmpty @Readonly List<String>(myNonEmptyStringSet)
```

- For exceptions



```
void monitorTemperature() throws @Critical TemperatureException { ... }
        void authenticate() throws @Fatal @Logged AccessDeniedException { ... }
```

Checker Framework

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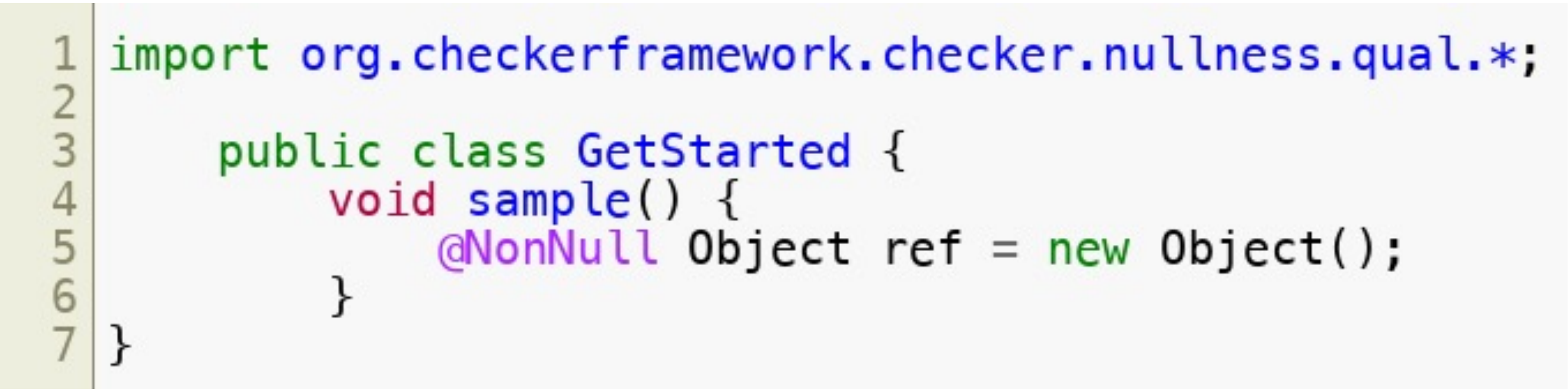
Benefits of the Checker Framework

- Helps get rid of
  - null pointer exceptions
  - unintended side effects
  - SQL injections
  - concurrency errors
  - mistaken equality tests
  - other run-time errors

Installation

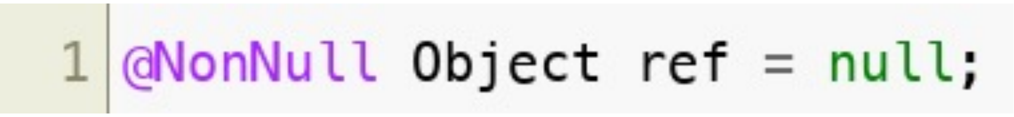
- Download the Checker Framework distribution
- Unzip it to create a checker-framework directory.
- (Optional) Configure
- IDE
- build system
- command shell to include the Checker Framework on the classpath

Using The Checker Framework



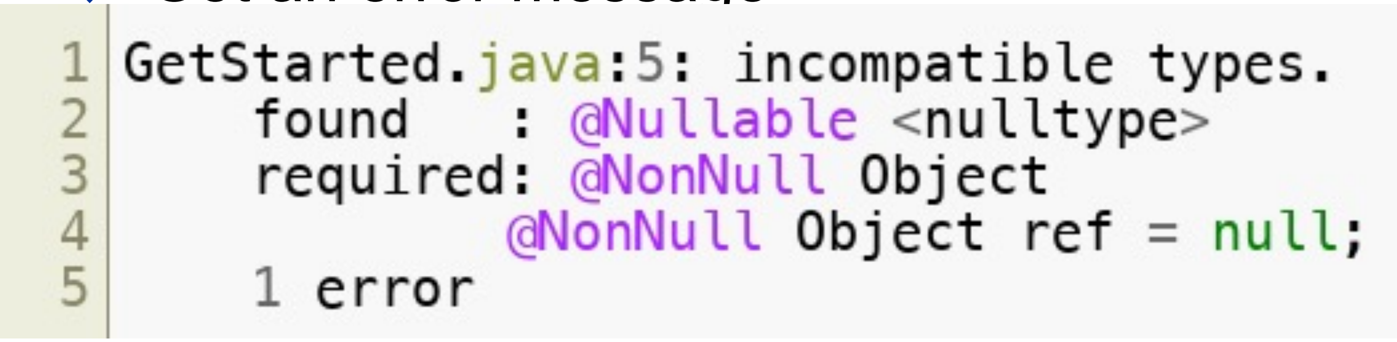
```java
import org.checkerframework.checker.nullness.qual.*;

    public class GetStarted {
        void sample() {
            @NonNull Object ref = new Object();
        }
}
```

Introduce an Error



```
@NonNull Object ref = null;
```

- Get an error message



```
GetStarted.java:5: incompatible types.
    found   : @Nullable <nulltype>
    required: @NonNull Object
            @NonNull Object ref = null;
    1 error
```

Application-layer security

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The application layer

- A layer in the Open Systems Interconnection (OSI) seven-layer model
- And in the TCP/IP protocol suite
- Consists of protocols that focus on process-to-process communication
- across an IP network
- Provides a firm communication interface and end-user services
- Security is provided through app-to-app negotiations

Transport-layer security

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Transport-layer Security

- Cryptographic protocols
- Designed to provide communications security
- Over a computer network

Where Transport-layer Security is Used

- Web browsing
- Email
- Instant messaging
- Voice over IP (VoIP)
- Websites use TLS
  - To secure all communications
    - servers
    - web browsers

Where Transport-layer Security is Used

- Aims
  - Privacy
  - Data integrity
- Properties
  - The connection is private (or secure)
  - Uses symmetric cryptography
    - to encrypt the data transmitted
  - The identity of the communicating parties can be authenticated
    - using public-key cryptography
  - The connection is reliable
    - Each message transmitted includes a message integrity check
    - Uses a message authentication code
    - Prevents undetected loss or alteration of the data

Message-layer security

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Securing the message

- More flexible than TLS
  - parts of the message can be signed or encrypted
  - rather than the entire message
- intermediaries are able to view parts of the message intended for them

Factor to Consider	Transport Layer	Message Layer
Your application interacts directly with the Web service	Transport layer HTTPS provides full message protection	Message layer message protection usually requires more work and overhead than transport layer

Encryption

- The encryption mechanism is a digital coding system to preserve confidentiality and integrity of data
- Encoding plaintext data into a protected and unreadable format
- Cipher: A standardized algorithm to transform original `plaintext` data into encrypted data (`ciphertext`) and vice versa
- The cipher is publicly known
- `Encryption Key` is used during the transformation
- Usually secret and shared among authorized parties
- Decryption is the revers function

Encryption, cont'd

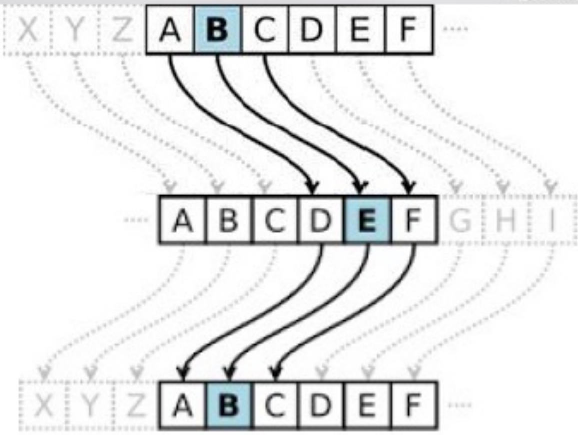
- Protection against:
- Traffic eavesdropping
- Malicious intermediary
- Insufficient authorization
- Overlapping trust boundaries security threats
- Two types of encryption:
- Symmetric (same key to encrypt and decrypt)
- Asymmetric (two keys,,one the inverse of the other)

Symmetric Key Cryptography

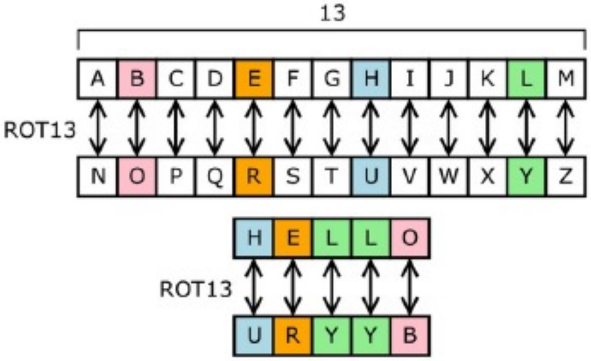
- Make use of a number of classical encryption techniques
- Substitution
- Each character in the text is replaced by another character of the same or different alphabet
- Transposition
- The order, but not the value, of the characters in the text is changed
- Iteration of the same steps multiple times

Example: An Old Technique

Caesar cipher: simple substitution cipher



- Replace each character in plain text with the character 3 positions forward in the alphabet
- If the end of the alphabet is reached, start over in the alphabet
- Note: we can change 3 with any other number (it is the key)



Advantages Of Symmetric Cryptography

- It is understandable and easy to use
- It is efficient
- Efficiency is a key consideration when messages are transmitted frequently and/or are lengthy
- Can be used for many other applications (hash functions, pseudo-random number generators, digital signatures)
- Can be easily combined

Limitations

- The users must share the same secret key
- During transmission of the key, someone may intercept the key
- The number of keys requires increases at a rapid rate as the number of users in the network increases
- Because of these reasons, secret key management challenges are significant
- A key distribution center (KDC) -a trusted third party- may be used for managing and distributing keys
- Secret key cryptography cannot provide an assurance of authentication
- Problem of non-repudiation

Asymmetric Cryptography

- A pair of private and public keys
- Private key remains with the owner; public key is distributed
- This solves the key distribution problem encountered in the use of secret keys
- One may own more than one keys pairs
- Knowledge of public key does not help in finding/deriving the related private key

Asymmetric Cryptography, cont'd

- Keys are related and complementary
- Plaintext encrypted with a private key can be decrypted using the related public key, and vice versa
- Public key encryption provides confidentiality, but does not offer integrity nor authenticity
- This is the base for the digital signatures

Asymmetric Encryption Cipher: RSA

- Created by Rivest, Shamir, and Adelman, named RSA
- Based on the notion that a product of two large prime numbers cannot be easily factored to determine the two prime numbers
- That is, going from results (the product of prime numbers) to inputs (prime numbers) is a nearly impossible task
- Although a public key is related to private key, it is nearly impossible to calculate the private key using the knowledge of its related public key

RSA Principles

- Consider blocks as large numbers
- Example: 2048 bit long number ~617 decimal long nmber
- Uses the modular arithmati (residuals)
- Example: 73 = 70 + 3 = 14 * 5 + 3 >> 73 mod 5 = 3
- Encryption and decryption are based on the concept of modular inverses:
- X is the inverse of Y modulo Z if X*Y=1 modulo Z
- Then (m^x)^y = (m^y)^x = m^1 = m

Advantages of Public Key Cryptography

- There is no need to communicate private key
- Related public key is widely distributed (not secret)
- A sender who private-key encrypts the message or any part thereof can be authenticated because no one else is supposed to have the sender's private key
- External parties can confidentially communicate with an owner of the key pair by sending a message encrypted using the owner's public key
- A brute-force attack on a message is time consuming and is nearly impossible

Limitations of Public Key Cryptography

- The use of PKC takes a significant amount of processing power, it is computationally intensive
- Therefore, it negatively affects efficiency of communication
- It is used selectively
- An entire message may not be encrypted using PKC
- Published keys may be altered by someone
- Additional measures to ensure that a valid public key of the owner is obtained before its use (PKI certificates)

Secure connection with SSL

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Secure connection with SSL

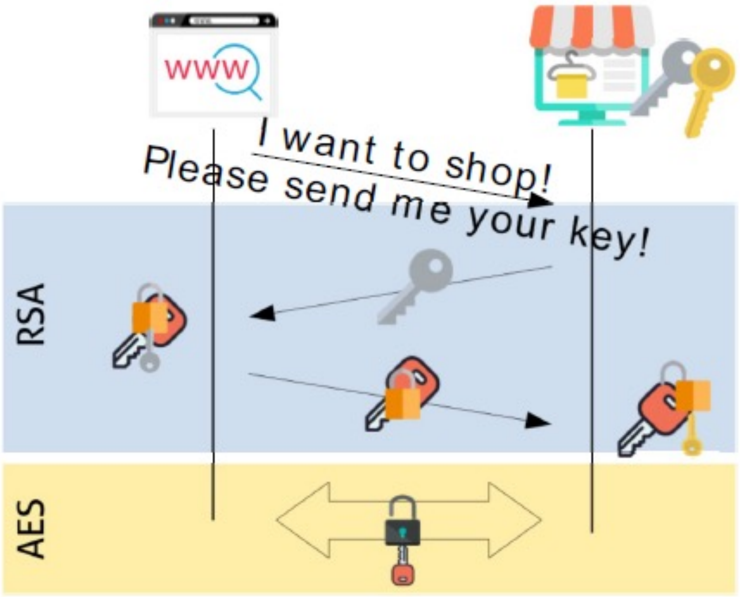
What Is It?

- A protocol by Netscape
- On Layer 4 (TCP) of OSI model

Cryptography Today

Cryptography in today life

- Symmetric and asymmetric cryptography are used together
- Asymmetric cryptography is used to exchange a key that is used with symmetric cryptography
  - Only few encryptions with RSA
  - All the traffic encrypted with AES



- Question:
  - can we trust public keys?

What Is SSL

- Is a standard security technology for establishing an encrypted link between a server and a client typically a web server (website) and a browser, or a mail server and a mail client (e.g., Outlook).

What Does It?

- Allows sensitive information like credit card information to be transmitted securely
- Determines variables of the encryption for both the link and the data being transmitted
- All browsers are able to interact with secured web servers using the SSL protocol
- Needs SSL certificates

How?

- 1 - Browser connects to a web server (website) secured with SSL (https). Browser requests that the server identify itself.
- 2 - Server sends a copy of its SSL Certificate, including the server's public key.
- 3 - Browser checks the certificate root against a list of trusted CAs

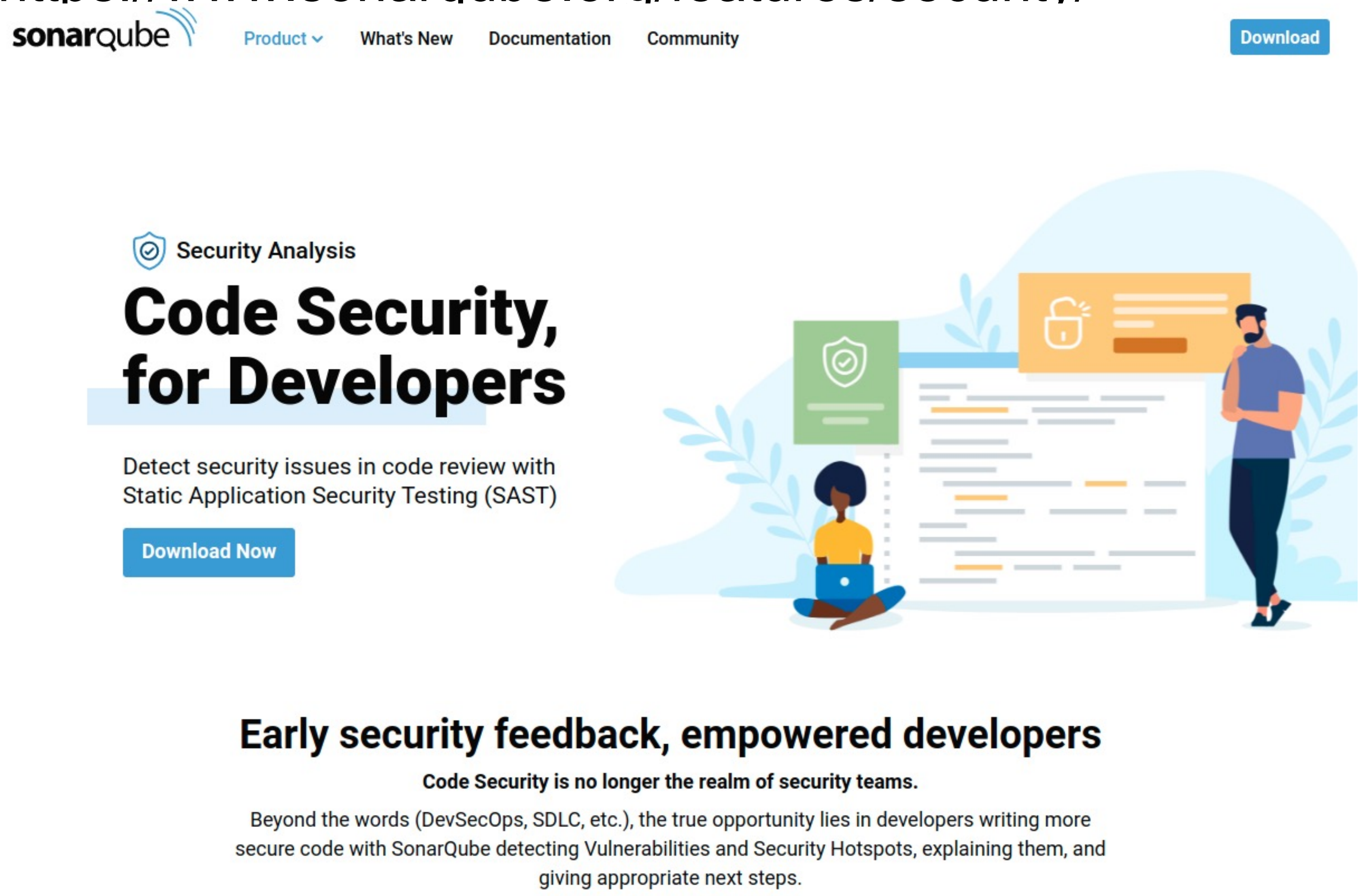
How? cont'd

- Then it creates, encrypts, and sends back a symmetric session key using the server’s public key.
- 4 - Server decrypts the symmetric session key using its private key and sends back an acknowledgement encrypted with the session key to start the encrypted session.
- 5 - Server and Browser now encrypt all transmitted data with the session key.

Flow Picture

Static code scanners

- Sonar Qube
- https://www.sonarqube.org/features/security/



Security Analysis

Code Security, for Developers

Detect security issues in code review with Static Application Security Testing (SAST)

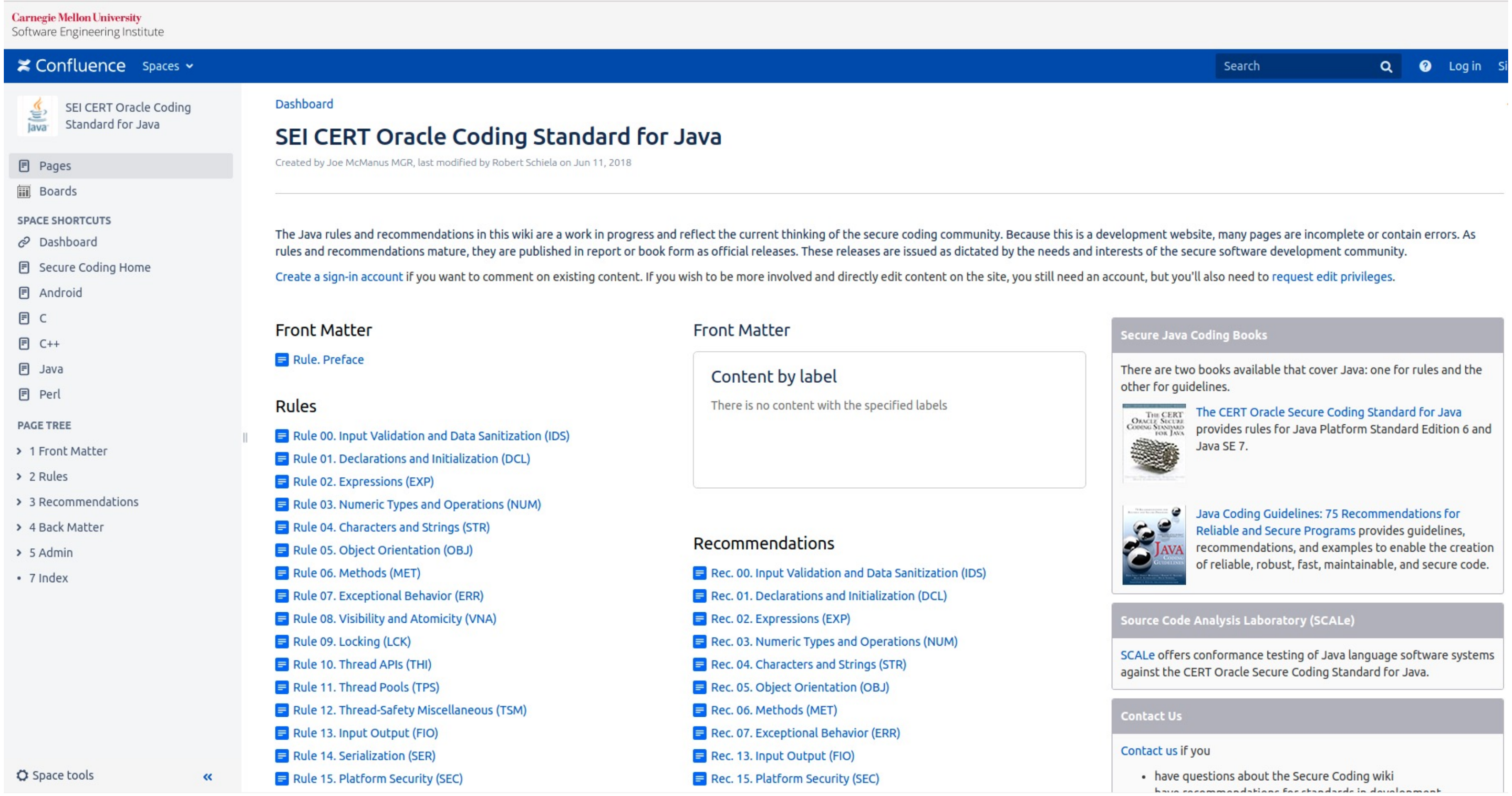
Early security feedback, empowered developers

Code Security is no longer the realm of security teams.

Beyond the words (DevSecOps, SDLC, etc.), the true opportunity lies in developers writing more secure code with SonarQube detecting Vulnerabilities and Security Hotspots, explaining them, and giving appropriate next steps.

Labs

- Labs for this section come from this link
- https://wiki.sei.cmu.edu/confluence/display/java/SEI+CERT+Oracle+Coding+Standard+for+Java



SEI CERT Oracle Coding Standard for Java

Created by Joe McManus MGR, last modified by Robert Schiela on Jun 11, 2018

The Java rules and recommendations in this wiki are a work in progress and reflect the current thinking of the secure coding community. Because this is a development website, many pages are incomplete or contain errors. As rules and recommendations mature, they are published in report or book form as official releases. These releases are issued as dictated by the needs and interests of the secure software development community.

Create a sign-in account if you want to comment on existing content. If you wish to be more involved and directly edit content on the site, you still need an account, but you'll also need to request edit privileges.

Front Matter

- Rule. Preface

Rules

- Rule 00. Input Validation and Data Sanitization (IDS)
- Rule 01. Declarations and Initialization (DCL)
- Rule 02. Expressions (EXP)
- Rule 03. Numeric Types and Operations (NUM)
- Rule 04. Characters and Strings (STR)
- Rule 05. Object Orientation (OBJ)
- Rule 06. Methods (MET)
- Rule 07. Exceptional Behavior (ERR)
- Rule 08. Visibility and Atomicity (VNA)
- Rule 09. Locking (LCK)
- Rule 10. Thread APIs (THI)
- Rule 11. Thread Pools (TPS)
- Rule 12. Thread-Safety Miscellaneous (TSM)
- Rule 13. Input Output (FIO)
- Rule 14. Serialization (SER)
- Rule 15. Platform Security (SEC)

Front Matter

Content by label

There is no content with the specified labels

Recommendations

- Rec. 00. Input Validation and Data Sanitization (IDS)
- Rec. 01. Declarations and Initialization (DCL)
- Rec. 02. Expressions (EXP)
- Rec. 03. Numeric Types and Operations (NUM)
- Rec. 04. Characters and Strings (STR)
- Rec. 05. Object Orientation (OBJ)
- Rec. 06. Methods (MET)
- Rec. 07. Exceptional Behavior (ERR)
- Rec. 13. Input Output (FIO)
- Rec. 15. Platform Security (SEC)

Secure Java Coding Books

There are two books available that cover Java: one for rules and the other for guidelines.

The CERT Oracle Secure Coding Standard for Java provides rules for Java Platform Standard Edition 6 and Java SE 7.

Java Coding Guidelines: 75 Recommendations for Reliable and Secure Programs provides guidelines, recommendations, and examples to enable the creation of reliable, robust, fast, maintainable, and secure code.

Source Code Analysis Laboratory (SCALe)

SCALe offers conformance testing of Java language software systems against the CERT Oracle Secure Coding Standard for Java.

Contact Us

Contact us if you

- have questions about the Secure Coding wiki
- have recommendations for standards in development