Sphinx: an anomaly-based Web Intrusion Detection System

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Agenda

- Overview
  - Web applications (in)security
- Current countermeasures
  - What are the scientists doing ?
- The definitive WIDS properties
- Our implementation
  - Training
  - Detection engine
  - Benchmarks
  - Generating signatures

Overview

- Web applications have become really popular nowadays
  - CMSs & BBSs
  - e-commerce & e-banking
  - Microsoft Live Search, Google Docs & Spreadsheets BETA
- New technologies support web applications popularity
  - back-end on DBMSs (2001)
  - Java/ActionScript (2003)
  - AJAX (2005)
- Web applications' content is particular attractive and this makes them one of the most interesting targets

Web applications (in)security

- Delivering a secure software is not easy: e.g. people with different skills contribute in open-source software

- From Symantec's "Internet Security Threat Report" (09/2006):
  - web application vulnerabilities account for 69% of total in Jan-Jun 2006
  - 78% of *easily exploitable vulnerabilities* are related to web applications (e.g. SQL Injection, XSS)

- SecurityFocus' Bugtraq is flooded every day with brand-new web application bugs

Current countermeasures

- NIDSs → Snort has more than 1200 signatures related to web attacks
  - SSL traffic cannot be easily analyzed
  - still playing *"cops and robbers"* with 0-day attacks

- Web Application Firewalls (WAFs) → *ModSecurity* is the most world-wide deployed WAF
  - Apache web server module → overcomes problems with SSL/POST data
  - imports Snort signatures as well as user-defined ones → deployment can become a complex task
  - few anomaly-detection capabilities on HTTP protocol fields only

What are the scientists doing ?

- Tools supporting source-code auditing [JKK06]
  - this is not always easy/possible (e.g. third-party CGIs/Java Servlets)
- Web server logs analysis [RVKA06]
  - recognizes the importance of parameter-based analysis
  - POST data can be missing/logs could be tampered
- Tailored solutions to catch SQL Injection/XSS attacks [VMV05]
  - source code needed/modified DBMS libraries to analyze incoming queries → what about, e.g., SQL Server ?
- Long text-based field (e.g. BBS messages/emails) are usually difficult to be analyzed

The definite WIDS (hopefully ;-)

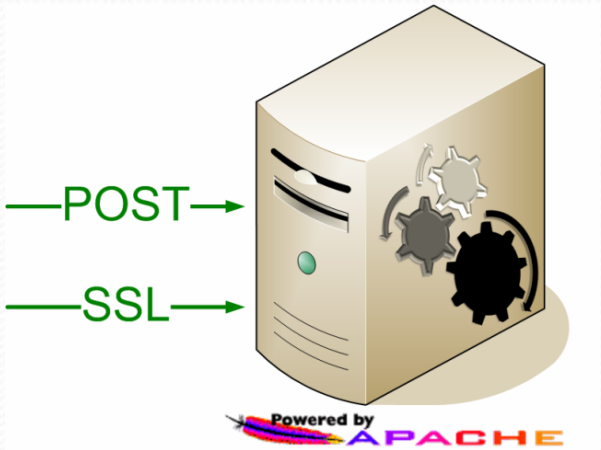
- Let's sketch the desired properties of a hypothetical Web Intrusion Detection System (WIDS)
  - Problem-free for :
    - SSL/POST data
    - unavailable source code
    - logs

  - Anomaly-detection on data and self-instructing, at least partially
    - 0-day attacks could be more easily detected
    - signatures could be automatically generated for certain query parameters to discover attacks → easier deployment

Just a "midsummer night's dream" ?

Our implementation

- Implemented as an Apache web server module
  - fully anomaly-based
  - analyzes SSL/POST data



- Different techniques are combined to increase detection and accuracy rates
  - pre-processing phase to clean the training data
  - parameter content analysis based on type → deals with long text content too

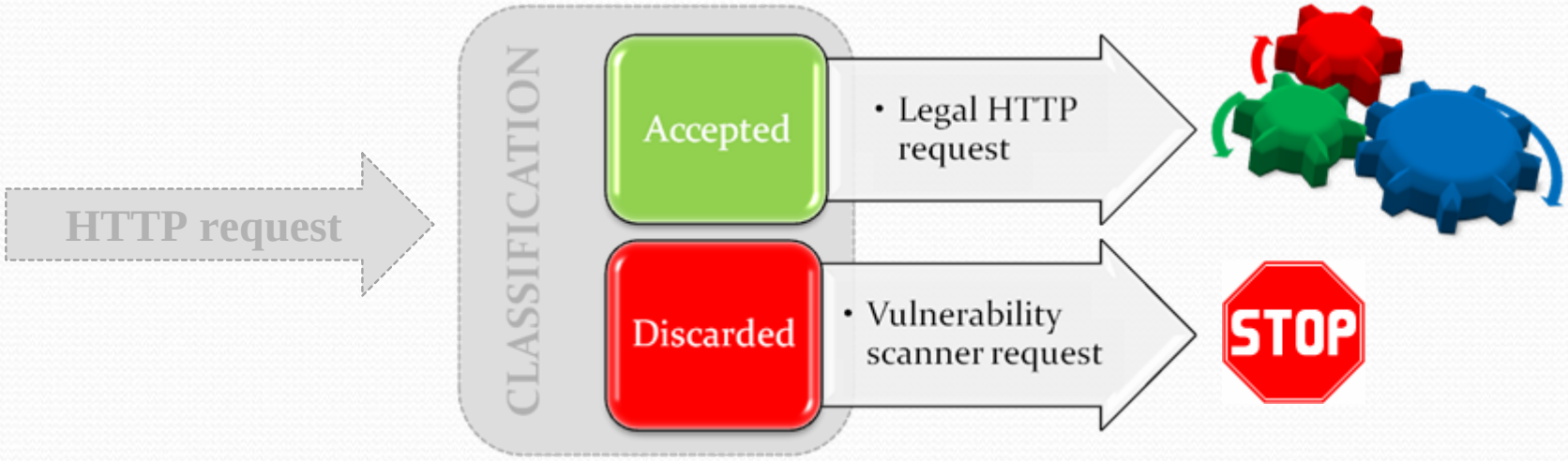
- Generates signatures in an automatic way for *ModSecurity*
  - makes deployment easier

Data pre-processing - 1

- Since the engine is anomaly-based, we need to train the WIDS before being able to detect attacks
- Nowadays a huge number of BOTnets and automatic scanners are constantly “monitoring” subnets, searching for well-known vulnerabilities
- This “noise” should be somehow avoided, since it affects the detection and the accuracy rates
  - in this situation, some information can be extracted to detect scanning activities

Data pre-processing - 2

- Pre-processing the training data makes possible to improve the performances (and size) of the anomaly engine models:
  - few parameters (received/sent bytes, response, duration)
  - low detection rate, but it suits our *pre-processing* purpose
  - typically discovers web scanner probes



What are we going to analyze ?

- A query has a typical structure (from the CMS PostNuke)

GET /modules.php?name=News&file=article&sid=25

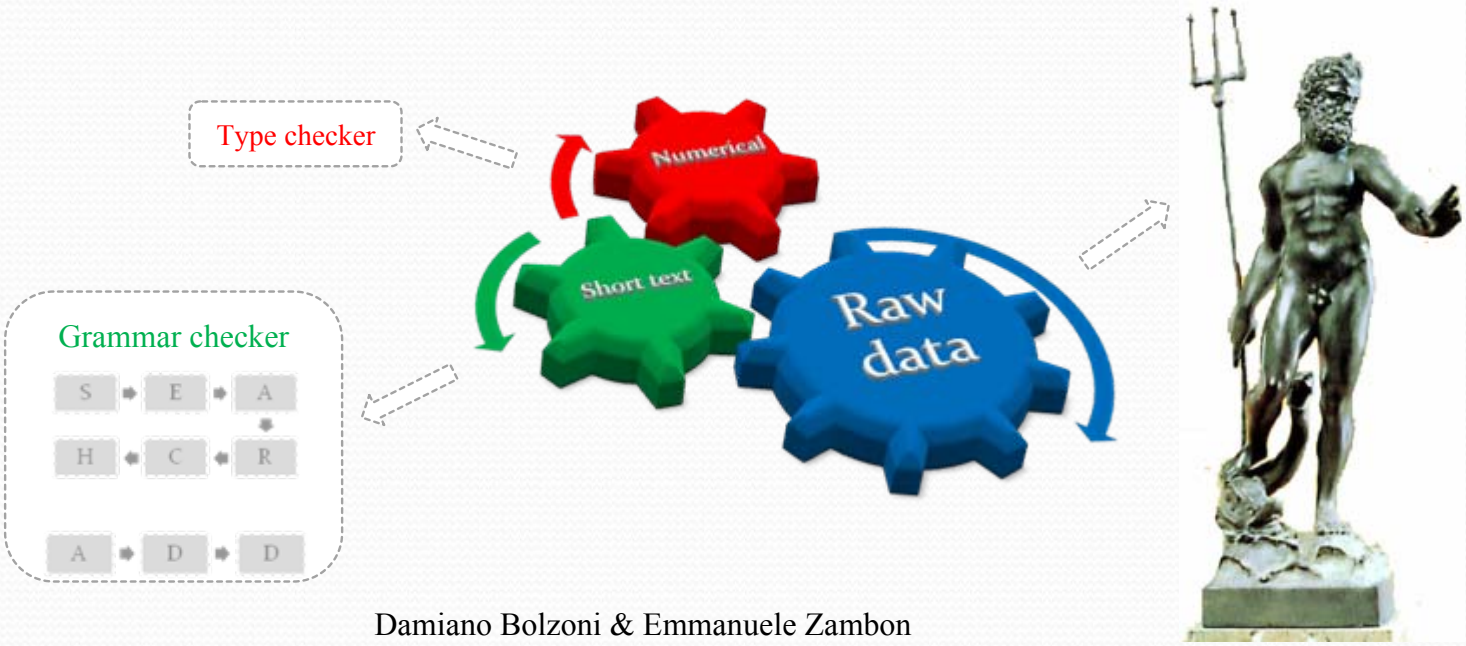
text-based parameter

numerical-based parameter

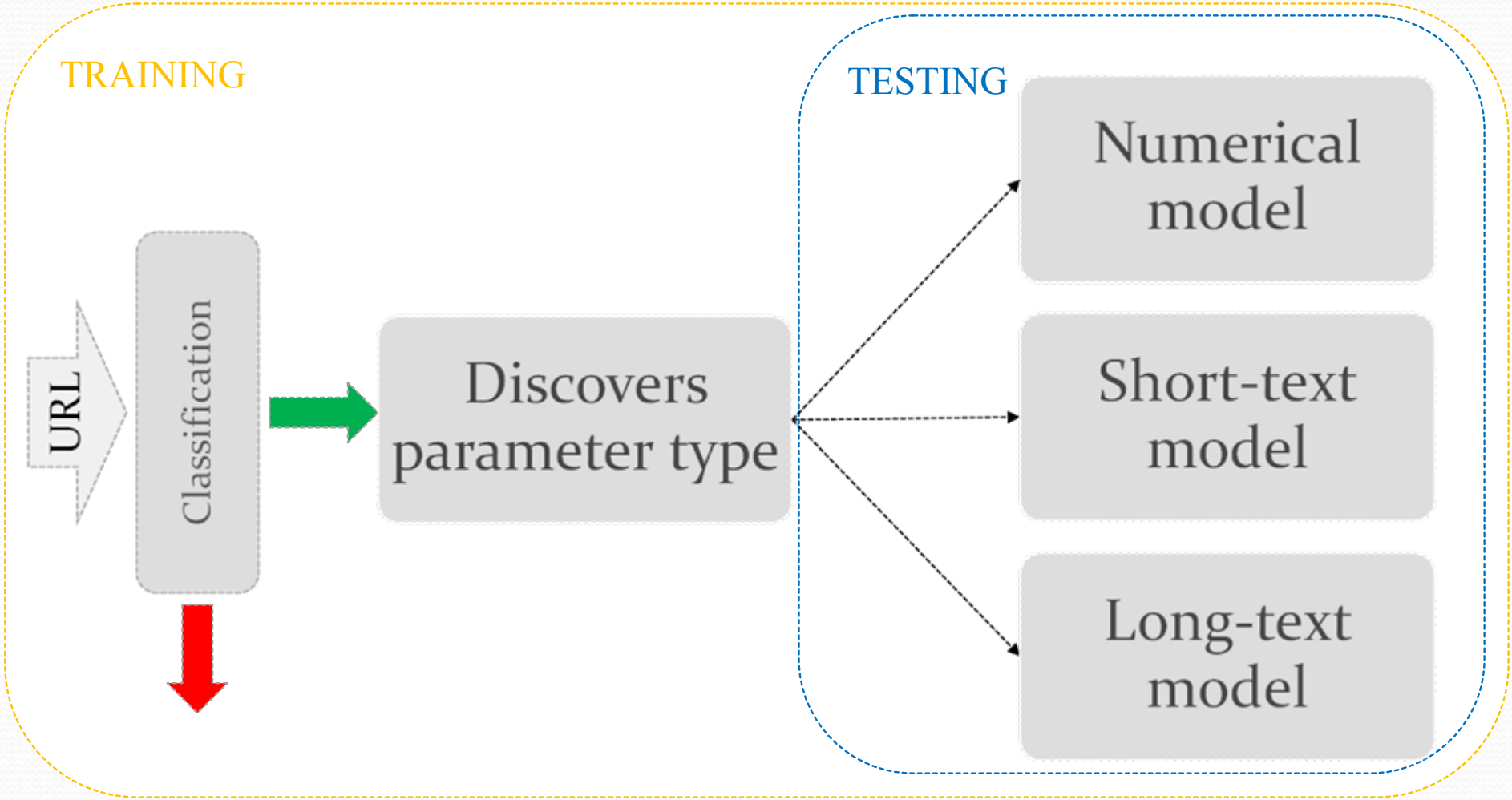
- The content analysis of a certain parameter gives the best information to detect attacks
  - if we observe integer values and later some text, that is likely to be an attack (e.g. SQL Injection or XSS)

The detection engine

- The detection engine "learns" the parameters type
  - numerical (mainly integer, e.g. DBMS table entries) → type checker
  - short text (almost fixed length/content) → grammar checker
  - raw data(variable length/content, e.g. email messages/executables) → modified version of our NIDS POSEIDON [BZEH06]



Data flow


TRAINING
TESTING
URL
Classification
Discovers parameter type
Numerical model
Short-text model
Long-text model

Numerical and short-text models

- Numerical model
  - discovers the numeric type (integer/decimal)
  - verifies that the following numbers are always of the same type

- Short-text model (fixed length or with slight variations)
  - an automaton is built to describe the character sequence
    - automata are merged in case of common sub-sequences
      - ***my_short_text_1*** and ***my_short_text_2*** → **my_short_text_(1|2)**
    - they can be generalized to reduce the size
      - e.g. session cookies: **abcd1234defg** → a* d* a*(but not @,+,/,…)
  - if we have too many automata (e.g. > 10), or too "long", for the same parameter, the detection becomes unfeasible → length information

search=(%(5(E(a|u|n|t|v|s|p|r|w|k|o|g|b|m|l|y|h|i|f|q|x|j|z|c|e))|s) | Go | plugin | external | None)

Raw data

- Our NIDS POSEIDON uses the single network packets to detect attacks
  - a neural network pre-classifies the traffic
  - an anomaly engine based on n-gram analysis detect attacks

- This time we have a stream of characters…
  - we divide the stream in blocks of N characters
  - each block is then passed to the detection engine → n-gram analysis
  - when we detect X anomalies in a single stream, we consider it anomalous

Threshold setting

- One of the most common problem with anomaly-based systems is setting properly the threshold(s)
  - it influences directly detection and false positive rates
- The long-text model has some values to be set
  - length of n-grams to be analyzed (N)
  - number of anomalous n-grams (X)
- These values have been found experimentally
  - N → 5
  - X → 5

Benchmarks – DARPA 1999

- Unfortunately, we do not have large (and complex!) public data set for testing WAFs
  - we can compare current results with the previous ones of our NIDS POSEIDON

DARPA 1999		
	DR	FP
POSEIDON	100%	0.0016%
WIDS	100%	0%

Easy…let's for something serious now!

Benchmarks – Private data set

- We collected the traffic directed to the web server hosting the web sites of our department
  - ~1000 requests per hour

- We found evidences of SQL Injection and XSS attacks (manually crafted), few buffer overflows and a lot of scan attempts for well-known paths

Private data set		
	DR	FP
POSEIDON	100%	2.85%
WIDS	100%	0.2%

Generating signatures - 1

- Anomaly-based systems are more powerful than signature-based ones but the latter are easier to be deployed…when we have the right signatures…
  - if we are deploying an *ad hoc* web application, most probably we need to spend a lot of time on writing signatures…
- We do NOT generate signatures from detected attacks (although it could be possible): our signatures define what is ALLOWED
- Our system can generate in an automatic way signatures for *ModProxy* for numerical-based parameters and most of the short text-based ones
  - SecRule QUERY_STRING "!^(id=\d+)" → accepts only digits for *id*
  - SecRule QUERY_STRING "!^(func=(add|delete|view))" → accepts only certain values for *func*

Generating signatures - 2

DEMO

Conclusion

- Our WIDS is the first totally anomaly-based solution
  - infers the parameter types (we define 3 basic types)
  - uses a different detection model for each parameter type
  - generates signatures in an automatic way to define what is allowed to pass → ModSecurity deployment made easier

- Currently, we are going to deploy it in a data center of an important Dutch outsourcer, offering security services (IDSs, log analysis and forensics)
  - customers are mainly e-commerce sites and banks
  - we want to evaluate especially the on-line capabilities

Q&A

(be my Sphinx!)

References

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[ModSecurity] http://www.modsecurity.org