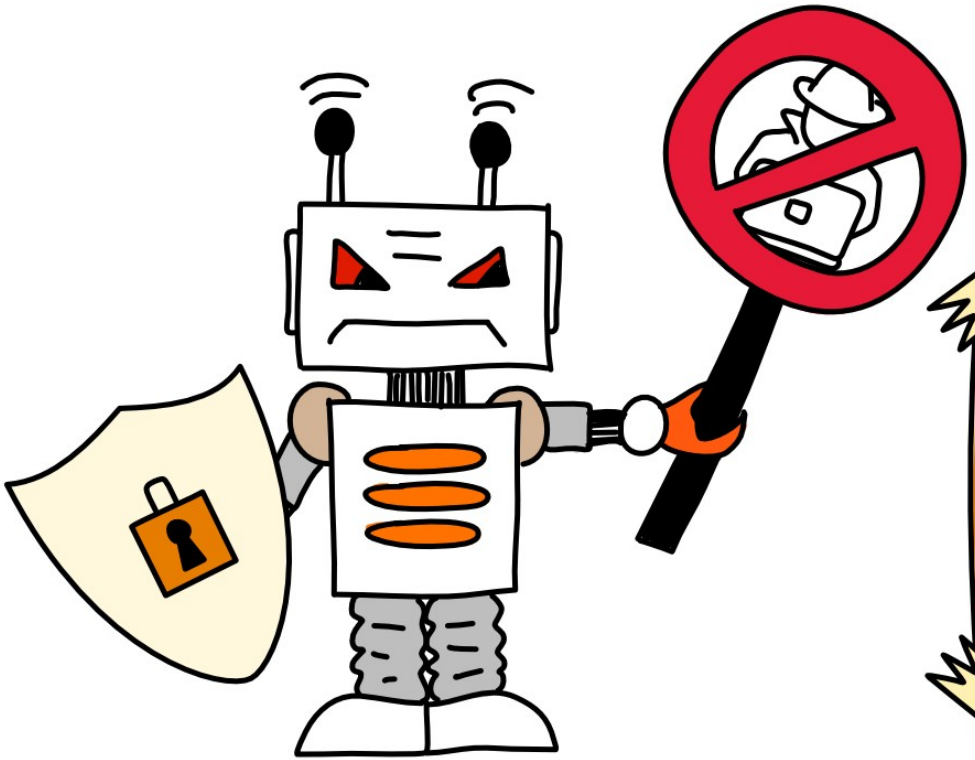


# MASCHINELLES LERNEN ZUR ERKENNUNG VON ANGRIFFEN AUF IT-SYSTEMEN NUTZEN

DANIEL ETZOLD

IT SECURITY SUMMIT

23.-25. NOVEMBER ONLINE

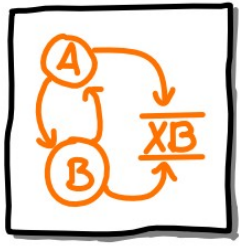
# ABOUT ME

@ETZOLD10

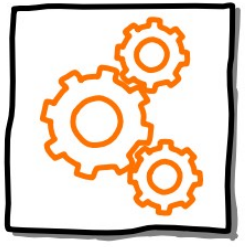
- IT SECURITY ARCHITECT
- 1&1 MAIL&MEDIA DEVELOPMENT&TECHNOLOGY GMBH

GMX WEB.DE mail.com

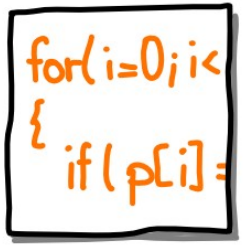
IN HOUSE CONSULTING




THREAT MODELING

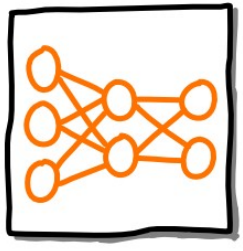


SECURE SOFTWARE DEVELOPMENT LIFECYCLE




CODE REVIEW

PENETRATION TESTING



MACHINE LEARNING & SECURITY

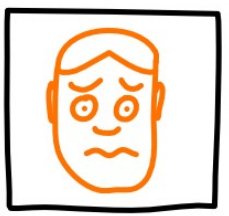
# DATA BREACHES


COMPANIES ARE HACKED REGULARLY

$>10^8$ RECORDS PER BREACH QUITE COMMON

| Entity | Year | Records | Organization type | Method | Sources |
|---|---|---|---|---|---|
| Betsson Group | 2020 | unknown | gaming | unknown | [49] |
| CheckPeople | 2020 | 56,000,000 | background check | unknown | [74] |
| Clearview AI | 2020 | 3,000,000,000 (Number of photos obtained) | information technology | hacked | [81] |
| Instagram | 2020 | 200,000,000 | social network | poor security | [181] |
| JailCore | 2020 | 36,000 | government | poor security | [186] |
| Koodo Mobile | 2020 | unknown | mobile carrier | hacked | [194] |
| Marriott International | 2020 | 5,200,000 | hotel | poor security/inside job | [211] |
| Nintendo (Nintendo Account) | 2020 | 160,000 | gaming | hacked | [238] |
| SlickWraps | 2020 | 377,428 | phone accessories | poor security | [268] |
| Tetrad | 2020 | 120,000,000 | market analysis | poor security | [301] |
| TikTok | 2020 | 42,000,000 | social media | poor security | [304] |
| Virgin Media | 2020 | 900,000 | mobile carrier | accidentally exposed | [338][339] |
| Wawa (company) | 2020 | 30,000,000 | retail | hacked | [345] |
| YouTube | 2020 | 4,000,000 | social media | poor security | [364] |
| Unknown agency (believed to be tied to United States Census Bureau) | 2020 | 200,000,000 | financial | accidentally published | [370] |

FINANCIAL LOSS

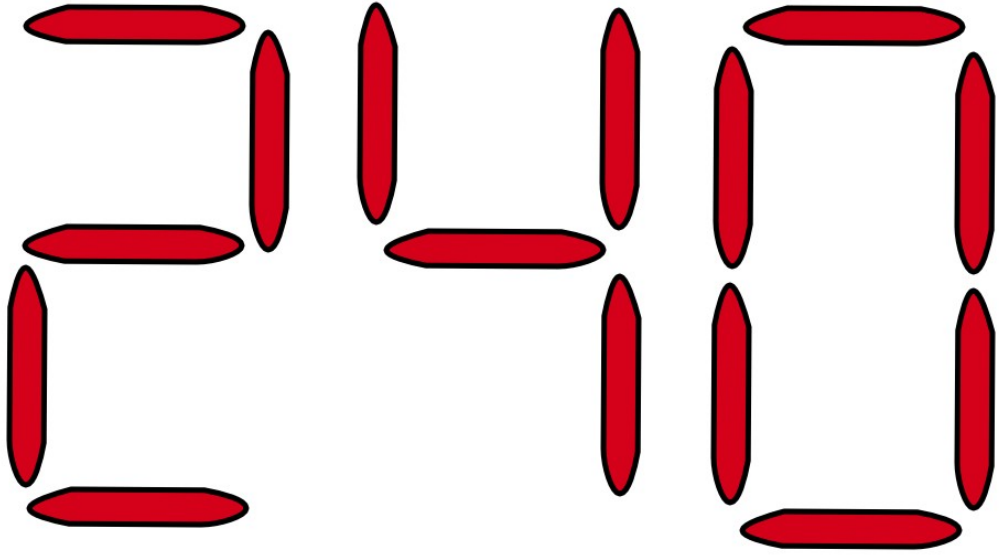


CUSTOMERS FEAR MISUSAGE

# STATUS QUO

MOST COMPANIES
ARE BAD AT DETECTING
INTRUSIONS

ON AVERAGE IT TAKES



DAYS UNTIL AN INTRUSION HAS BEEN DISCOVERED

# AGENDA

ATTACK VECTORS

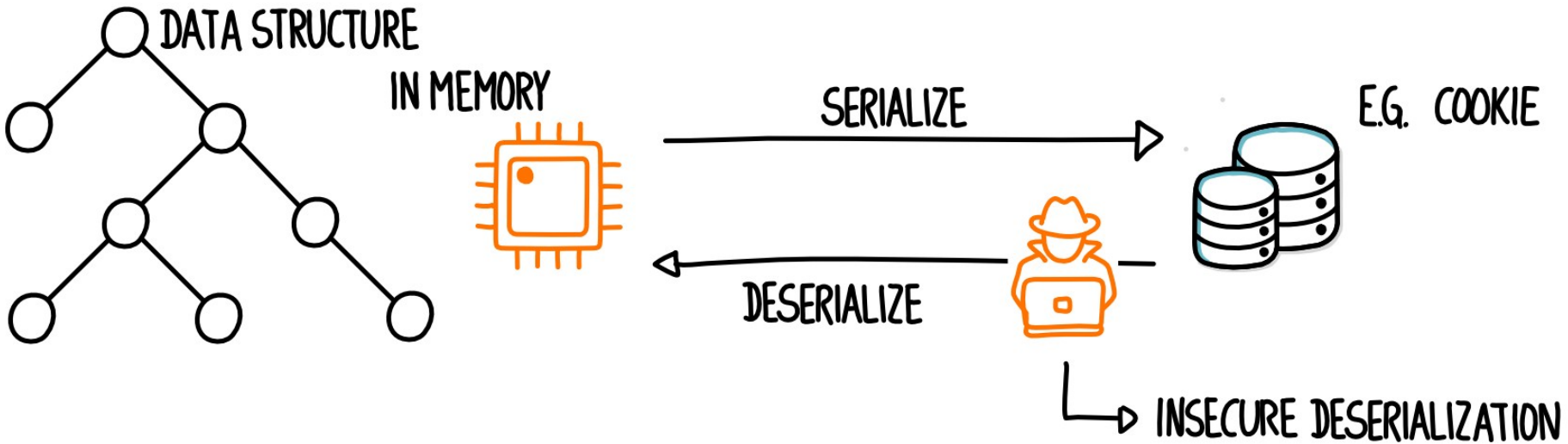
VULNERABILITY PREVENTION AND INTRUSION DETECTION

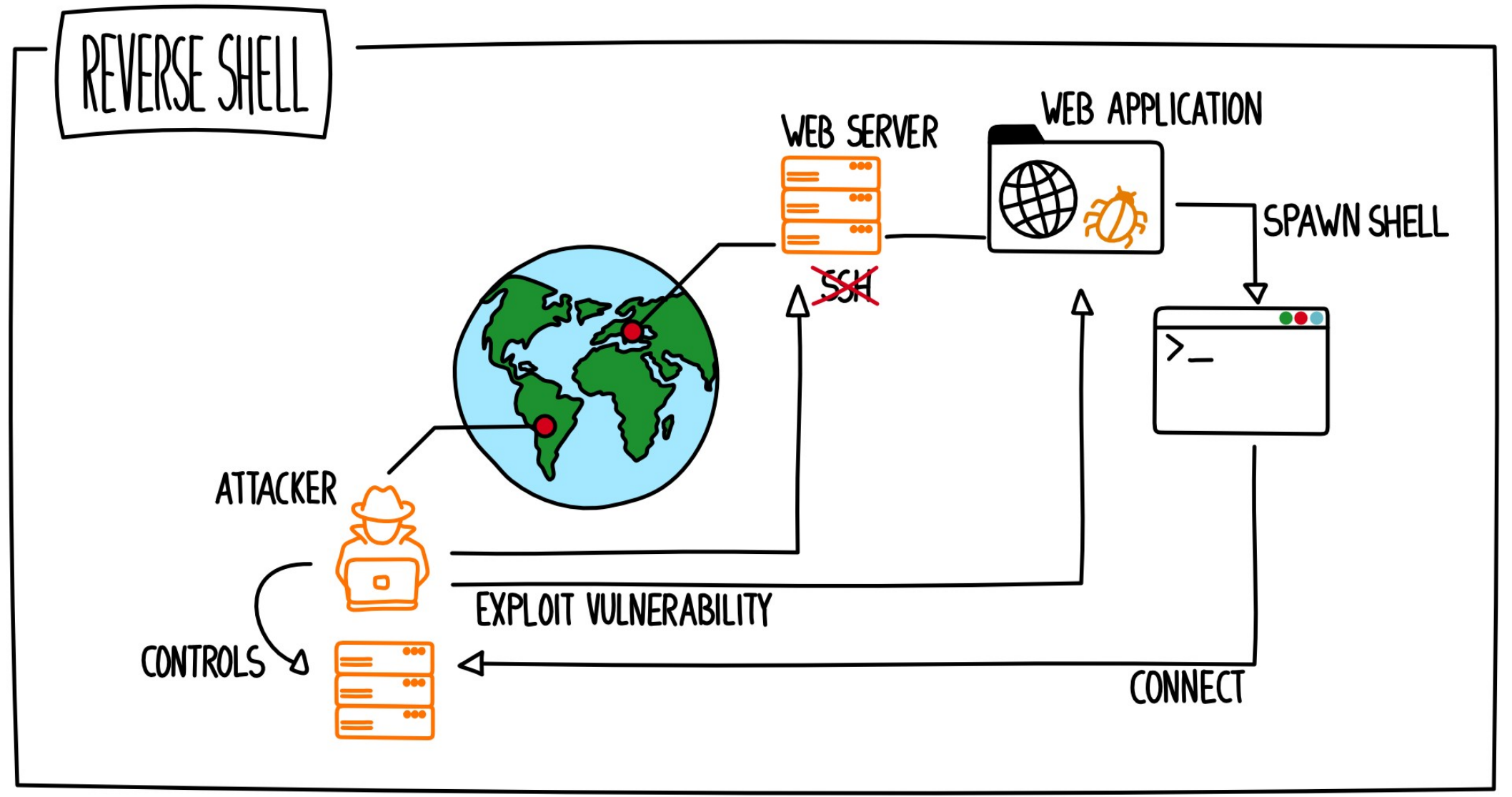
BASICS OF MACHINE LEARNING

EXAMPLES:

SYSTEMS CALLS
LOG FILE VISUALIZATION
AUTOENCODER

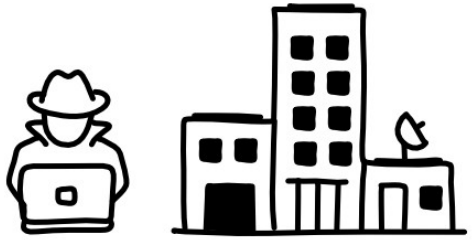
# EXAMPLE


DATA STRUCTURE
IN MEMORY
SERIALIZE
E.G. COOKIE
DESERIALIZE
INSECURE DESERIALIZATION


REVERSE SHELL
WEB SERVER
WEB APPLICATION
SPAWN SHELL
SSH
ATTACKER
EXPLOIT VULNERABILITY
CONTROLS
CONNECT

# ATTACK VECTORS

HOW ATTACKERS GET ACCESS TO A COMPANY NETWORK



BACKDOORS

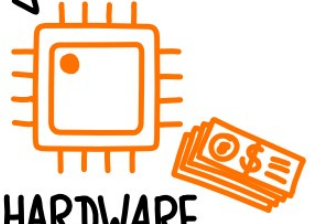
PARTNERS

CLEANING STAFF

EMPLOYEES

VULNERABILITIES IN SOFTWARE

OPEN SOURCE SOFTWARE



HARDWARE

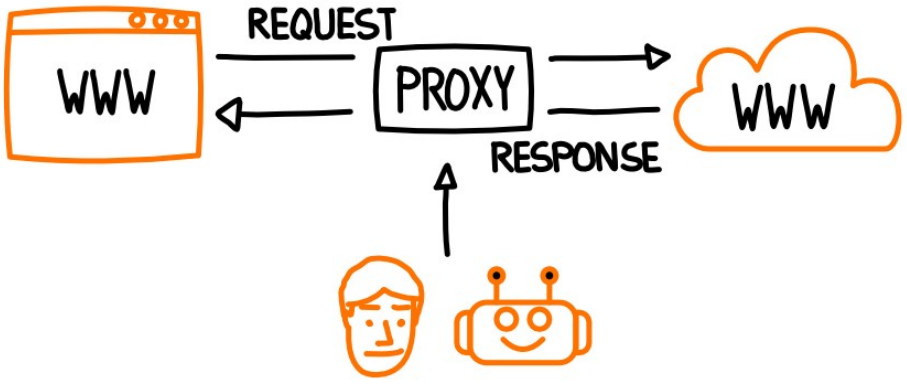
SPEAR PHISHING

WATERING HOLE ATTACK

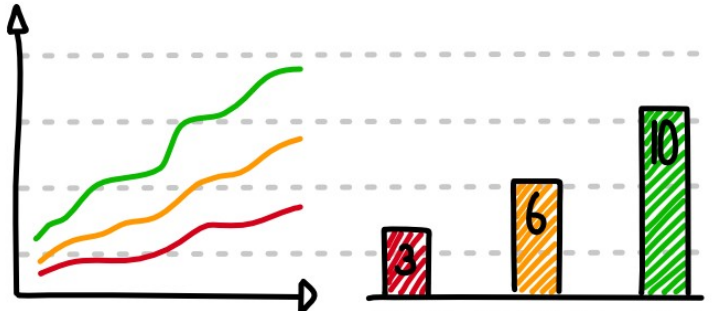
# OWASP

## OPEN WEB APPLICATION SECURITY PROJECT

### OWASP ZAP




### OWASP DEPENDENCY TRACK



# OWASP TOP 10

INJECTIONS

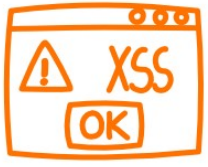

BROKEN AUTHENTICATION


SENSITIVE DATA EXPOSURE


XML EXTERNAL ENTITIES

BROKEN ACCESS CONTROL

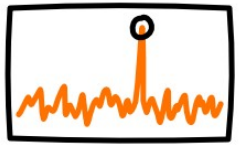
SECURITY MISCONFIGURATION




CROSS SITE SCRIPTING


INSECURE DESERIALIZATION

COMPONENTS WITH KNOWN VULNERABILITIES



INSUFFICIENT LOGGING AND MONITORING

# DETECT SQL INJECTIONS


WEB APPLICATION WITH LOGIN — VERIFIES CREDENTIALS VIA

WARNING

NEVER DO THIS

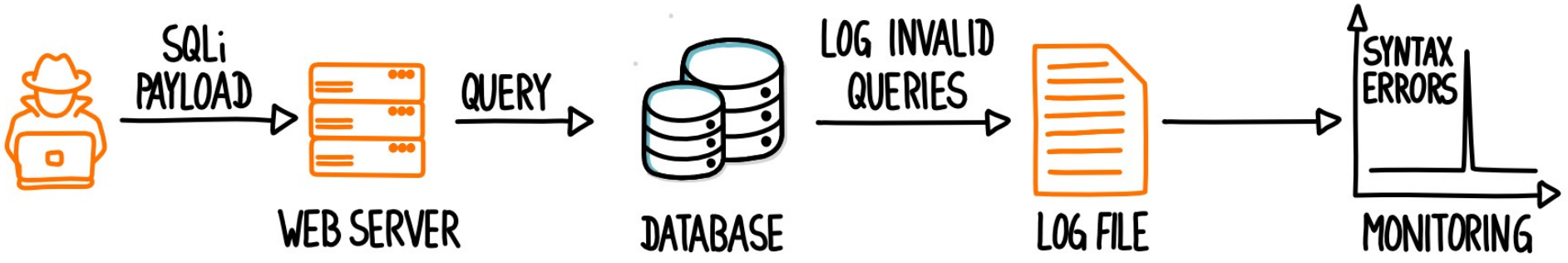
SELECT userid FROM users WHERE email='foo@example.com' AND pwd='password';

' OR 1=1;- -

SELECT userid FROM users WHERE email='' OR 1=1;- -' AND pwd='password';

# DETECT SQL INJECTIONS

WITH LOGGING




DRAWBACK: PASSIVE APPROACH — SOLUTION → DEFENSE IN DEPTH

# DETECT SQL INJECTIONS

WITH A SIMPLE LEARNING APPROACH

Database Intrusion Detection Systems (DIDs): Insider Threat Detection via Behavioural-based Anomaly Detection Systems — A Brief Survey of Concepts and Approaches
arxiv.org/abs/2011.02308

WITH THIS → 

IT'S GETTING COMPLICATED

SQLi PAYLOAD →

WEB SERVER

QUERY →

QUERY ANALYZING COMPONENT

→ 

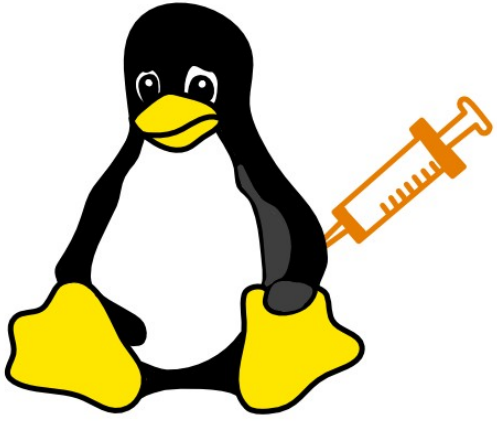
DATABASE

← ARBITRARY QUERIES

ADVANTAGE: CAN ACTIVELY BLOCK QUERIES

PHASE 1: BUILD MODEL
PHASE 2: USE MODEL TO CLASSIFY QUERIES

# OS COMMAND INJECTION

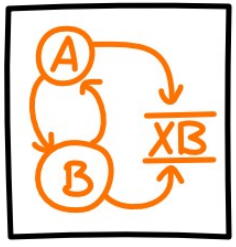


```
HTTPS://FOO.COM?ID=123
```

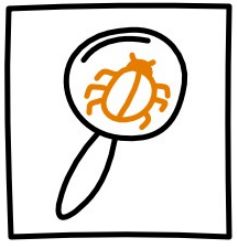
```
OS.SYSTEM("SCAN.SH "+$REQUEST["ID"])
```

# VULNERABILITY PREVENTION

AWARENESS

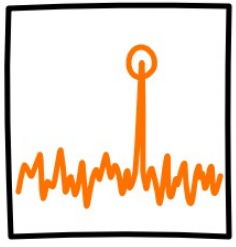



THREAT MODELING (E.G. STRIDE)



STATIC / DYNAMIC APPLICATION SECURITY TESTING

PENETRATION TESTING



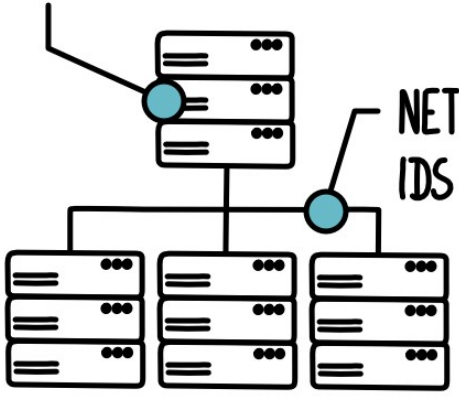
MONITORING

PRE-LIVE → LIVE

# INTRUSION DETECTION SYSTEMS

## VARIANTS

HOST-BASED IDS



NETWORK-BASED IDS

## TECHNOLOGIES USED FOR IDS

### RULES / SIGNATURES

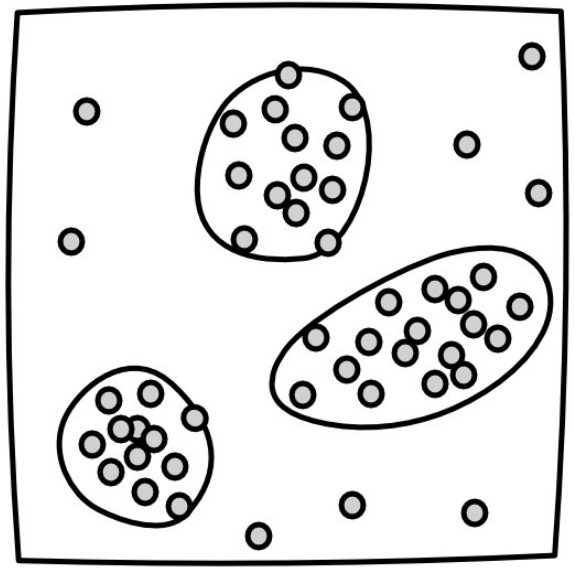
- ⊕ FAST
- ⊕ LOW FALSE POSITIVES
- ⊖ CANNOT DETECT UNKNOWN ATTACKS
- ⊖ NEED REGULAR UPDATES

### MACHINE LEARNING

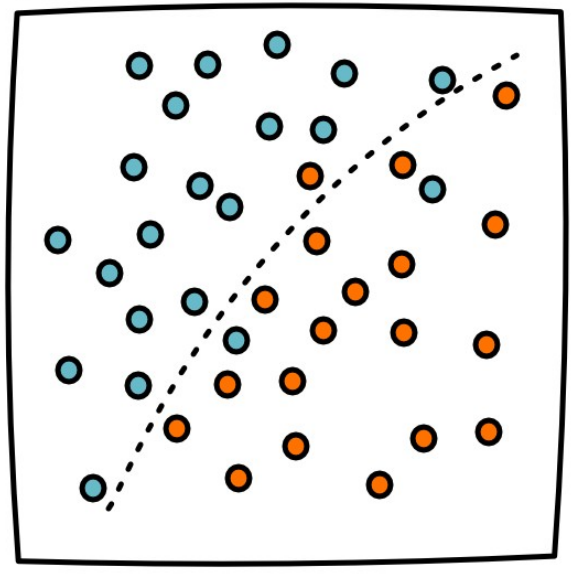
- ⊕ CAN DETECT UNKNOWN ATTACKS
- ⊖ HAVE FALSE POSITIVES
- ⊖ NEED RETRAINING
- ⊖ BLACK BOX

# MACHINE LEARNING

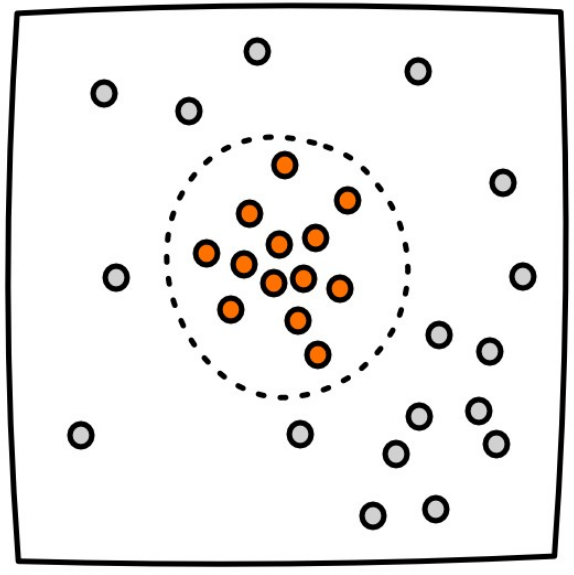
## UNSUPERVISED LEARNING



## SUPERVISED LEARNING

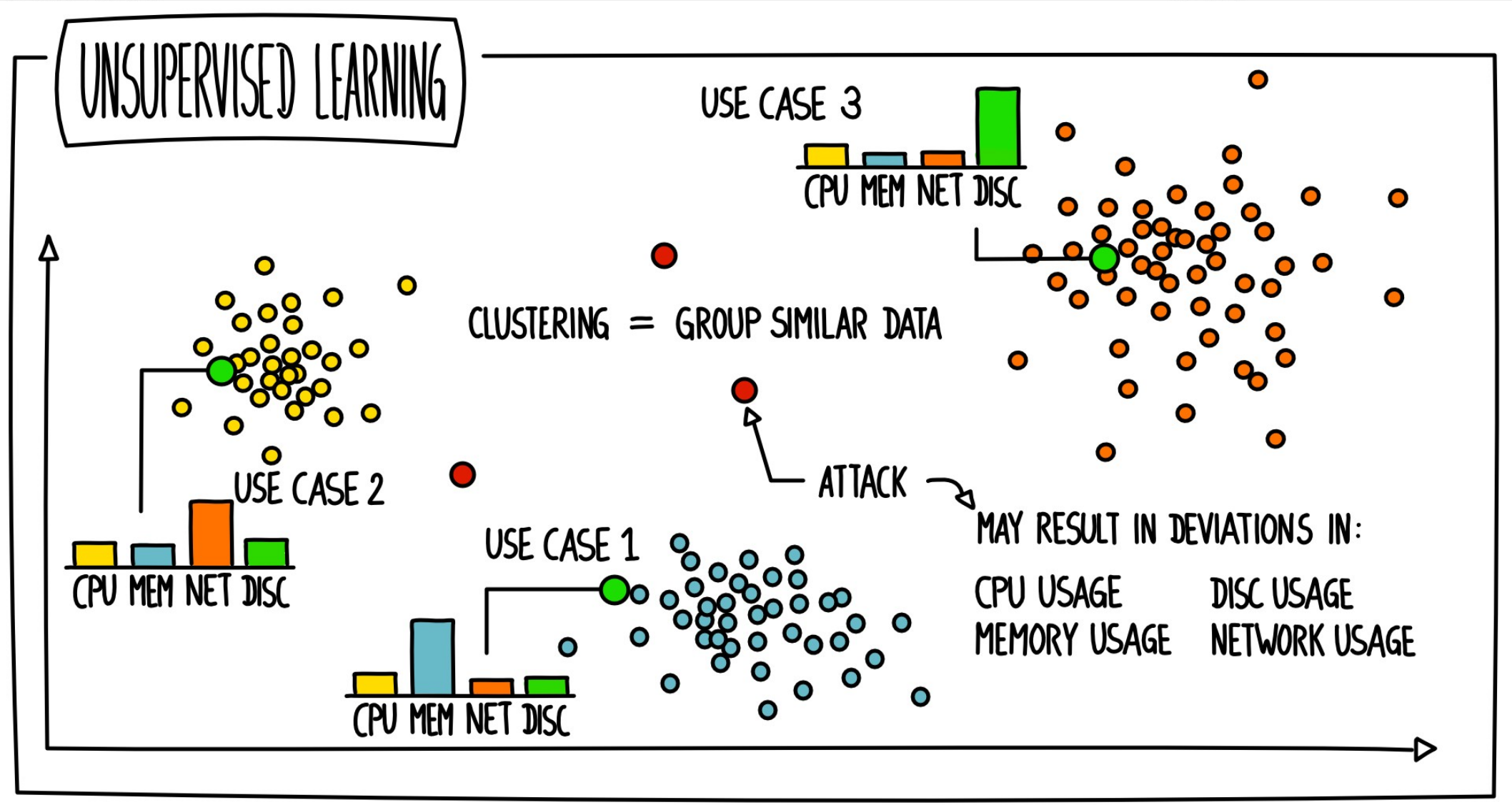


## SEMI-SUPERVISED LEARNING



LABELS UNKNOWN

LABELS KNOWN

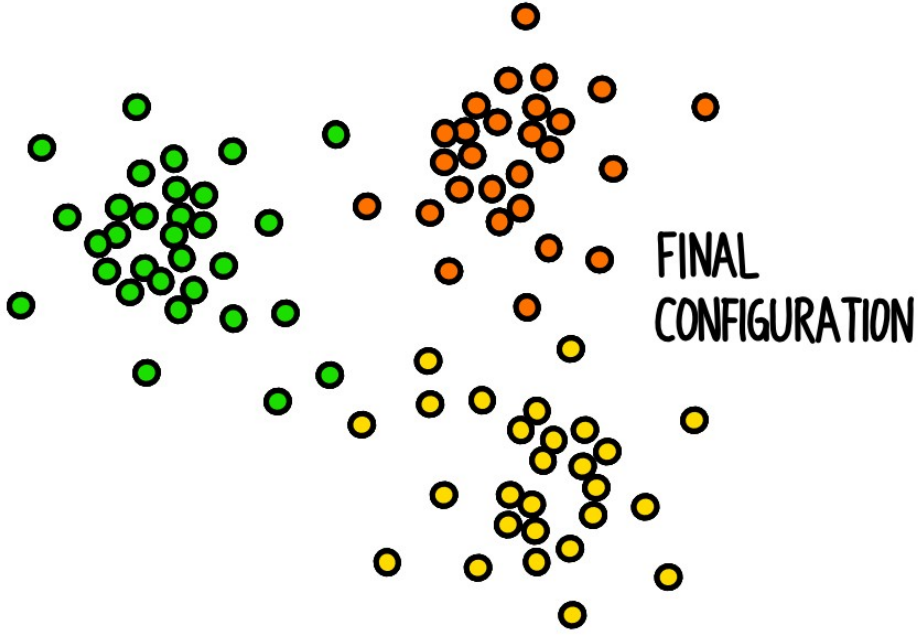

UNSUPERVISED LEARNING
USE CASE 3
CPU MEM NET DISC
CLUSTERING = GROUP SIMILAR DATA
USE CASE 2
CPU MEM NET DISC
ATTACK
MAY RESULT IN DEVIATIONS IN:
USE CASE 1
CPU USAGE
DISC USAGE
MEMORY USAGE
NETWORK USAGE
CPU MEM NET DISC

# K-MEANS

## STEPS

1. INITIALIZE CLUSTER CENTERS
2. ASSIGN DATA POINTS TO CLUSTER CENTERS
3. RECOMPUTE CLUSTER CENTERS

REPEAT




## DRAWBACKS

- NUMBER OF CLUSTERS MUST BE KNOWN
- NOT DETERMINISTIC
- ALL DATA POINTS ARE ASSIGNED TO CLUSTERS

# DBSCAN

## ADVANTAGES

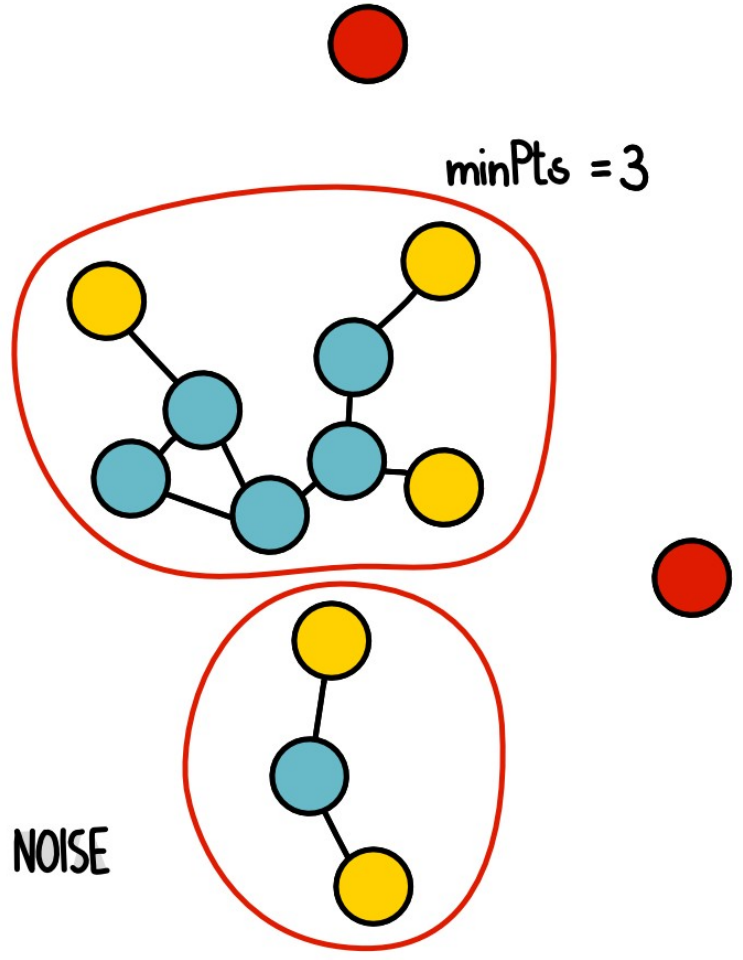
- MOSTLY DETERMINISTIC
- NUMBER IS DETERMINED AUTOMATICALLY
- CAN DETECT OUTLIERS
- FINDS CLUSTERS WITH ARBITRARY SHAPES

## PARAMETERS

- ε
- minPts

## STEPS

- FOR EACH POINT FIND ALL POINTS IN ε NEIGHBORHOOD
- IDENTIFY THE CORE POINTS
- FIND CONNECTED COMPONENTS OF CORE POINTS
- ASSIGN NON-CORE POINTS TO CLUSTERS



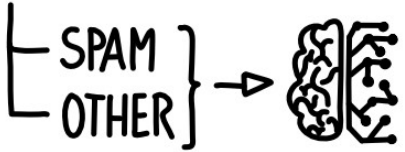
# SUPERVISED LEARNING

- LABELS OF DATA IS KNOWN
- TYPICAL USE CASE: CLASSIFICATION
  E.G. SPAM FILTER

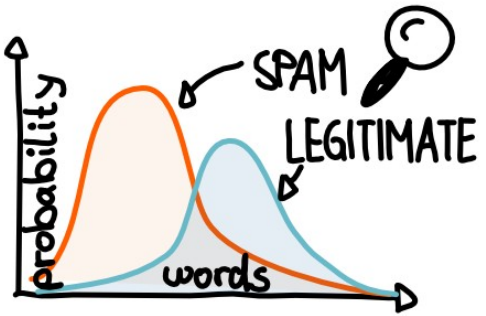
EXISTS FOR
~20 YEARS

DATA FOR TRAINING

MAILBOX



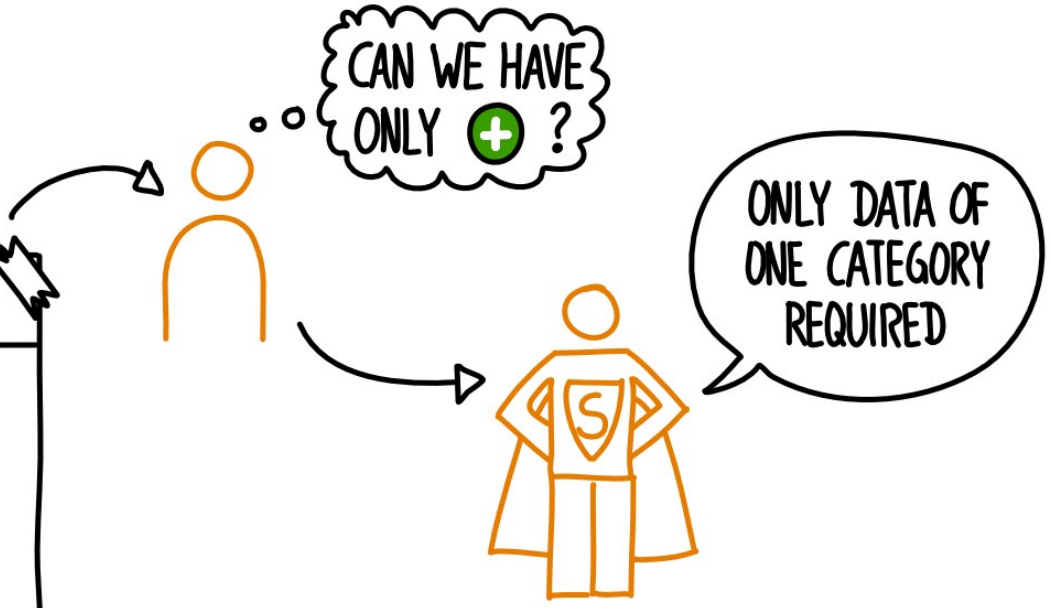

EXPLOIT DIFFERENCES
IN WORD DISTRIBUTIONS




DRAWBACKS

- CANNOT DETECT UNKNOWN PATTERNS
- DIFFICULT TO GET EXAMPLES OF ATTACKS (→ IMBALANCED DATA)

# SEMI-SUPERVISED LEARNING




## RECAP

### SUPERVISED

- \+ SIMPLE
- \+ HIGH ACCURACY
- – EXAMPLES FOR ATTACKS REQUIRED

### UNSUPERVISED

- \+ NO LABELED DATA REQUIRED
- – MAINLY FOR MANUAL ANALYSIS

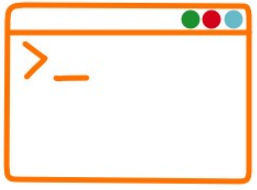
- \+ CAN DETECT UNKNOWN ATTACKS
- – FALSE POSITIVES

# DETECT RCEs

## USEFUL DATA SOURCES

- NETWORK TRAFFIC
- USER ACTIVITIES
- SYSTEM LOGS
- APPLICATION LOGS

## REVERSE SHELL



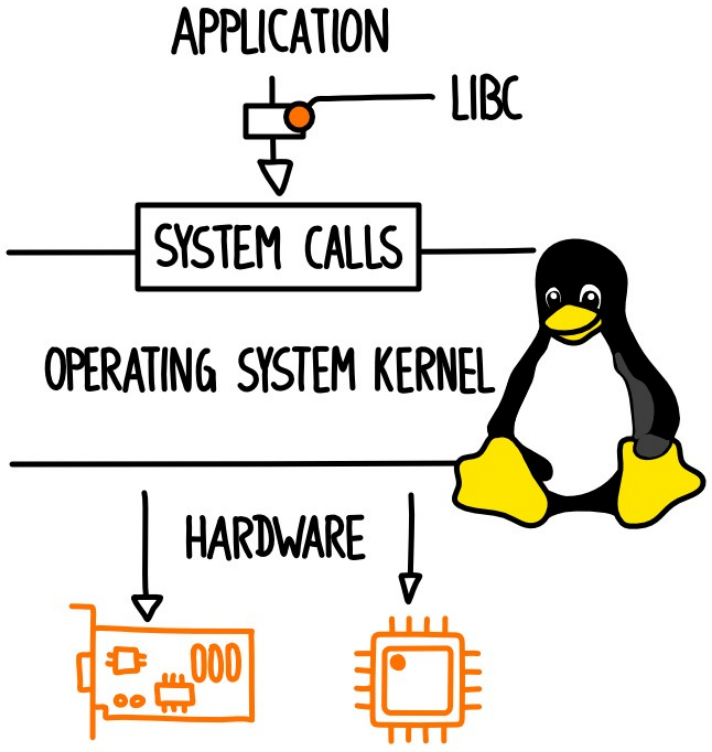

- CONNECTION OPEN FOR LONG TIME
- TYPICALLY IDLE
- SUSPICIOUS IP ADDRESS

INTERESTING

## COLLECTING DATA WITH OSQUERY

- DEVELOPED BY FACEBOOK
- RUNS EVERYWHERE
- SQL API

# SYSTEM CALLS

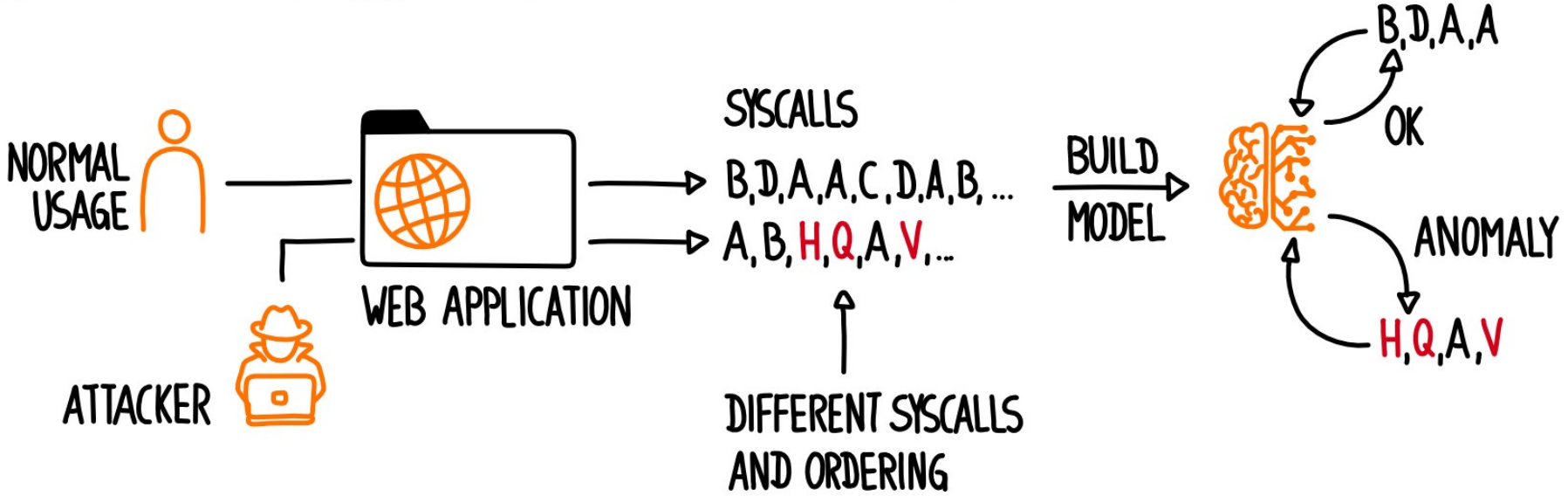



EXAMPLES

| CATEGORY | SYSTEM CALLS |
|---|---|
| CONTROL PROCESS | KILL |
| FILE OPERATIONS | OPEN, READ, WRITE |
| NETWORK | ACCEPT, LISTEN, SOCKET |

# SYSTEM CALLS

ASSUMPTION: EACH APPLICATION USES ONLY A SUBSET OF SYSCALLS



# SYSTEM CALLS

## EXAMPLE OF A SEQUENCE

OPEN, READ, READ, OPEN, WRITE, WRITE, CLOSE, CLOSE, FORK, EXIT

SW 1

SW 2 → SEQUENCE WITH N SYSCALL
SLIDING WINDOW LENGTH M
⇒ N-M+1 SUBSEQUENCES

SW 1 → OPEN, READ, READ

SW 2 → READ, READ, OPEN

BUILD A SUPER SIMPLE MODEL →

= SET OF ALL UNIQUE SUBSEQUENCES → SUPER SIMPLE TRAINING

## FIRST APPROACH

- READ COMPLETE SEQUENCE
- CREATE FEATURE VECTOR

## PROBLEM

WHAT TO DO WITH
UNLIMITED OR VERY SEQUENCE

## SECOND APPROACH

- SLIDING WINDOW

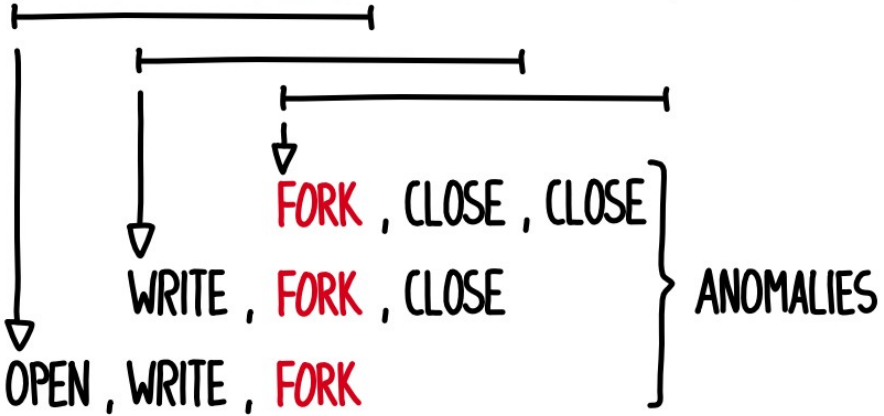
# SYSTEM CALLS

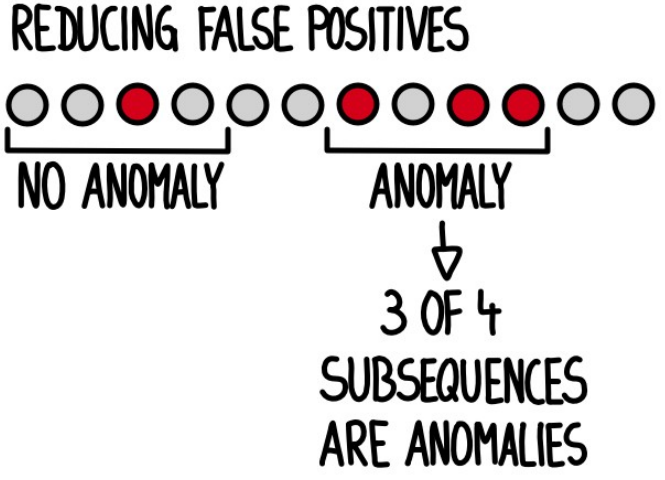
## EXAMPLE OF A SEQUENCE

OPEN , READ , READ , OPEN , WRITE , WRITE , CLOSE , CLOSE , FORK , EXIT

## NEW SEQUENCE

OPEN , READ , READ , OPEN , WRITE , FORK , CLOSE , CLOSE , FORK , EXIT



# DO SYSTEM CALLS WORK

CAN WE DIFFER BETWEEN APPLICATION USING SYSTEM CALLS

ANALYZING 4 SCENARIOS

A) PHP APPLICATION

B) POSTGRESQL

C) POSTFIX

D) POP3

REC

RECORDED MILLIONS OF SYSTEM CALLS

RESULTS

- SMALL SUBSET OF SYSTEM CALLS IS CALLED
  A,B,D: ~40 E: 13
- SEQUENCES OF LENGTH 1 DON'T WORK

TESTS WITH LENGTH 3

WITH THIS OBSERVATION

IN THEORY

$\sim 330^3 \sim$ 36 MIO 3-TUPLES

$\sim 40^3$

IN PRACTICE

| | A | B | C | D |
|---|---|---|---|---|
| | 250 | 250 | 150 | 88 |

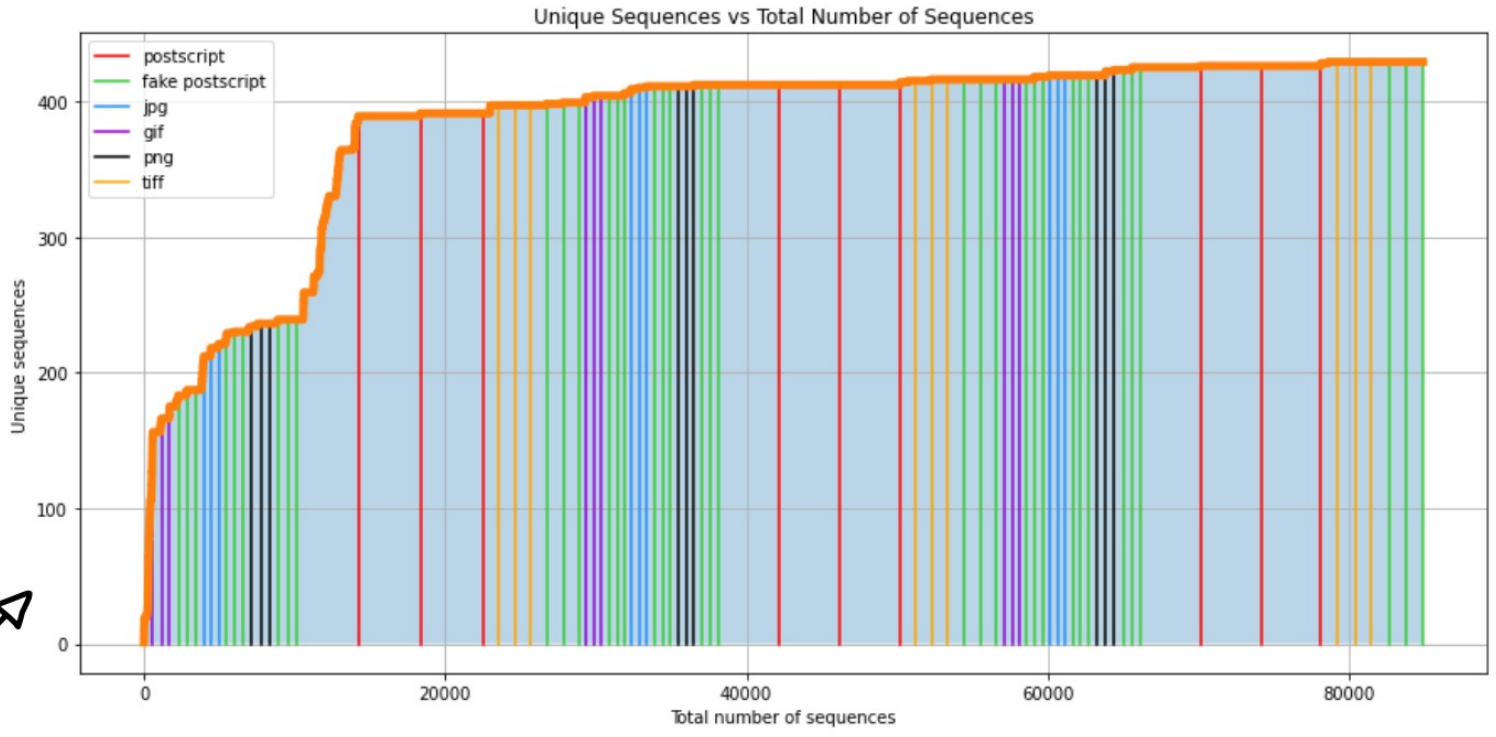
INTERSECTION

| | B | C | D |
|---|---|---|---|
| A | 9 | 4 | 1 |
| B | | 8 | 3 |
| C | | | 10 |

# EXAMPLE: CONVERT

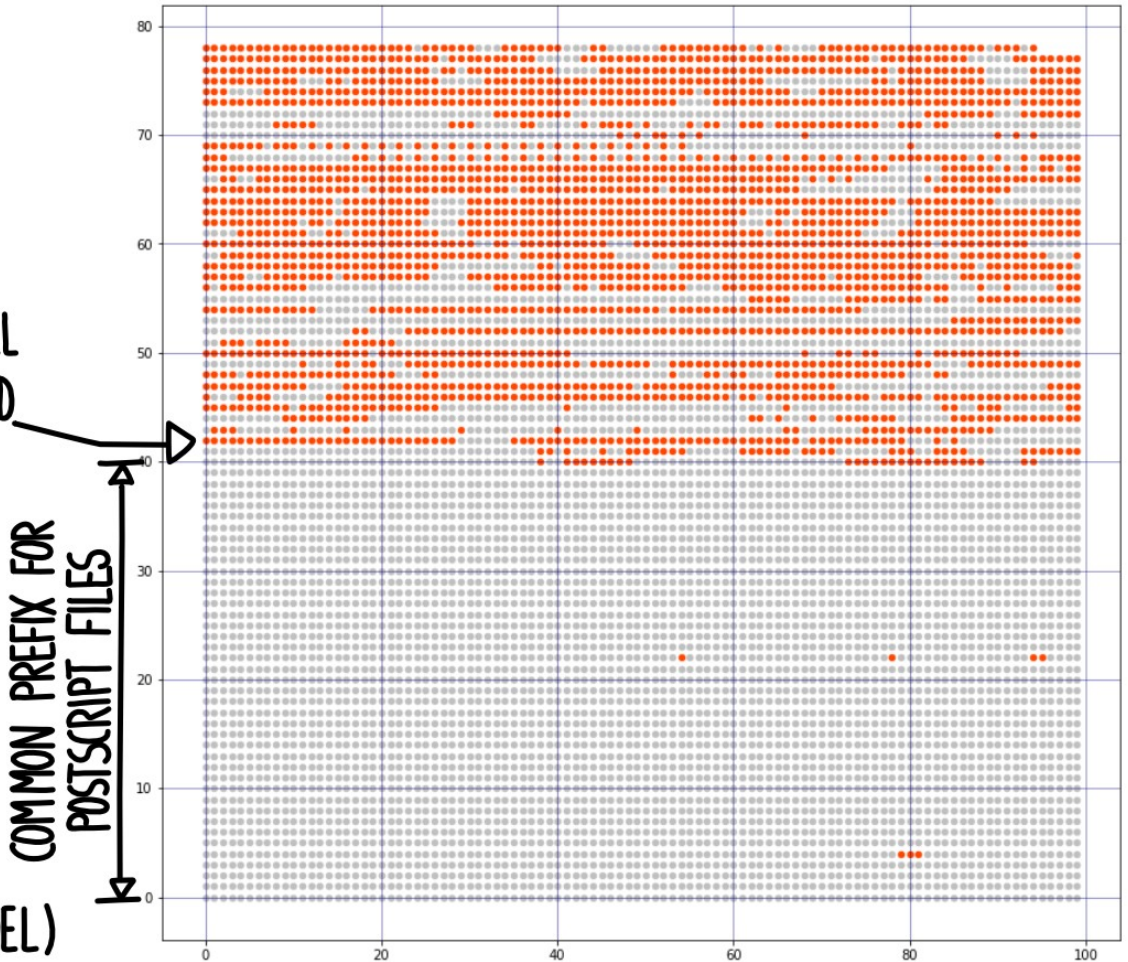
WHEN CAN WE STOP LEARNING

WHEN NO NEW SEQUENCES ARE OBSERVED



# EXAMPLE: CONVERT

EXECUTED SEQUENCES WHEN REVERSE SHELL IS LAUNCHED

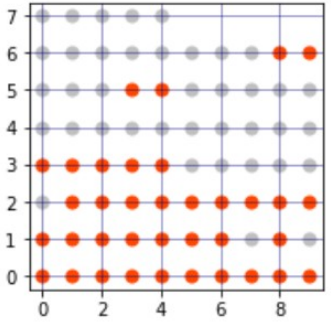



- UNKNOWN SEQUENCE
- KNOWN SEQUENCE (I.E. SEQUENCE IN MODEL)

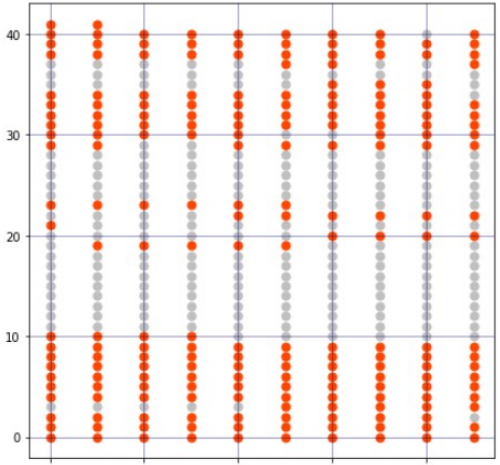
# EXAMPLE: CONVERT

EXECUTED SEQUENCES FOR...

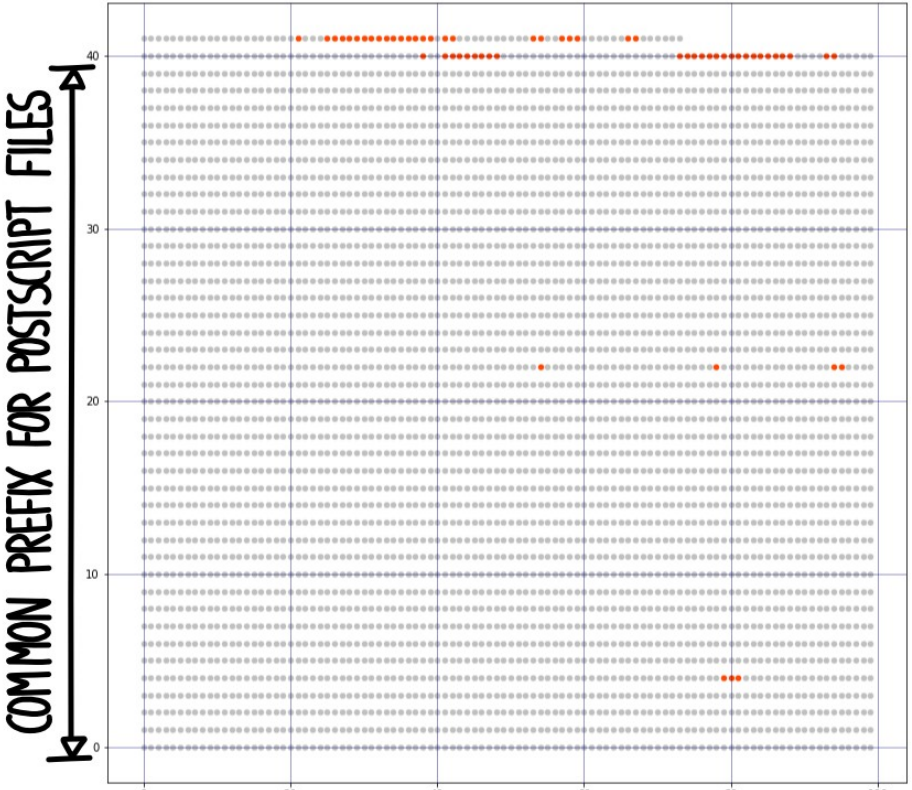
EXIT (EXECUTED IN RS.)



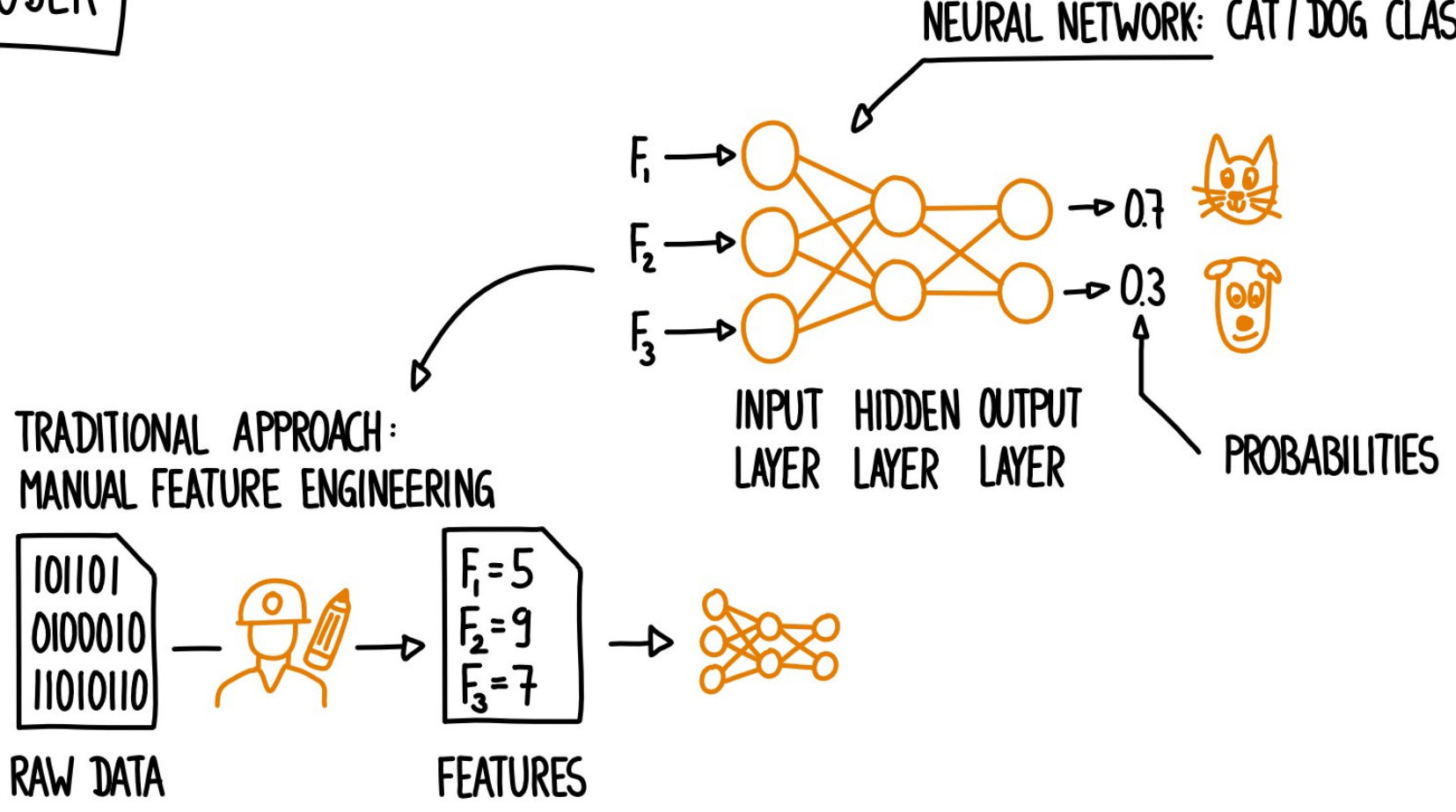

LS (EXECUTED IN RS.)



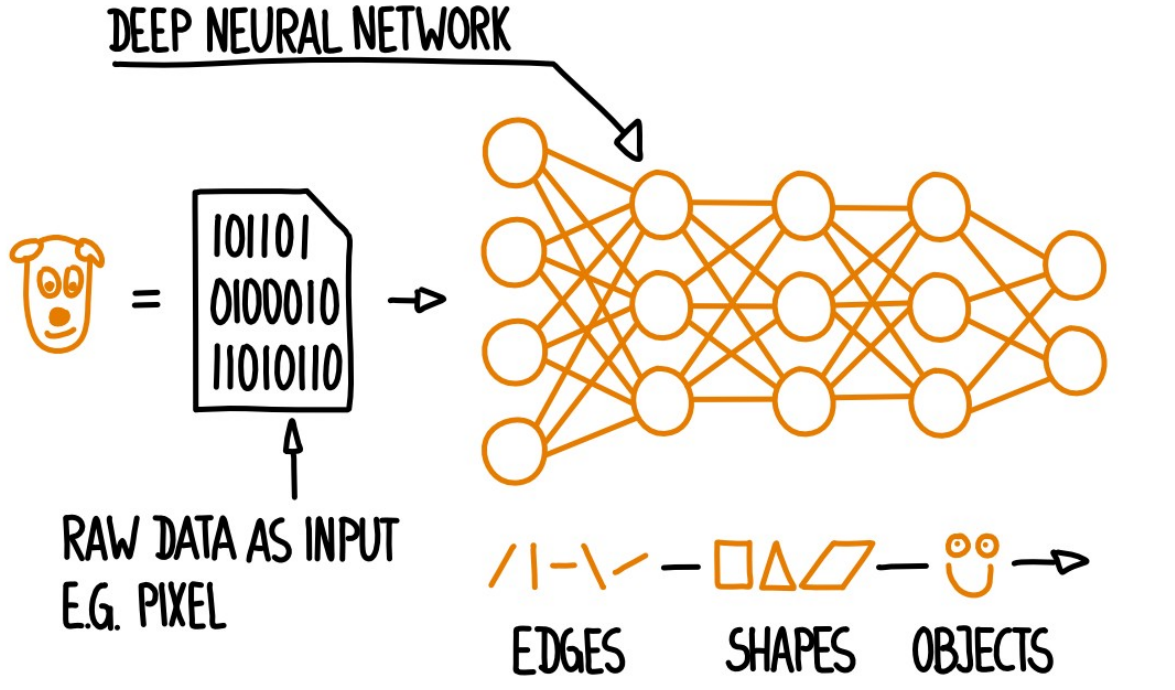

CAT /ETC/PASSWD



# AUTOENCODER

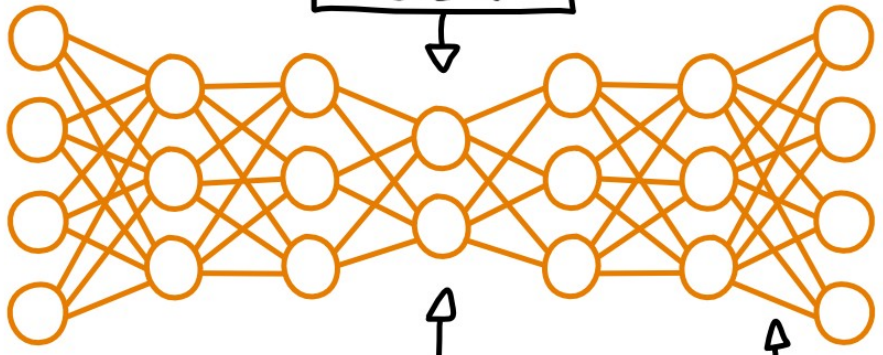


# AUTOENCODER

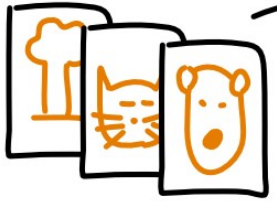


# AUTOENCODER

- #OUTPUT NEURONS = #INPUT NEURONS
- GOAL: $f(x) = x$ — CHALLENGING DUE TO



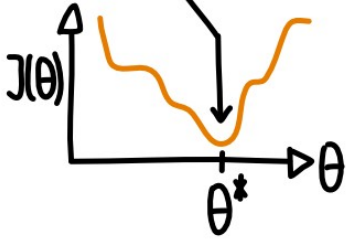

TRAINING

1. INITIALIZE PARAMERS $\theta$
2. 
3. COMPUTE $J(\theta)$
   COMPUTE $\frac{\partial}{\partial \theta_i} J(\theta)$
4. UPDATE PARAMETERS

4. REPEAT UNTIL UPDATE $< \varepsilon$

$J(\theta)$ = ERROR OF NETWORK

GOAL: FIND $\theta$ SUCH THAT $J(\theta)$ IS MINIMIZED



# VISUALIZE LOGFILES

TYPICAL CONTENT

CHALLENGES

- LOGFILES ARE UNSTRUCTURED → SEARCHING FOR ANOMALIES IS DIFFICULT
- DYNAMIC CONTENT {X}

- ONE LINE = ONE EVENT
- ERROR, INFO, NOTICE
- DATE, TIME, IP, ...

EXAMPLE

```
2020-09-07 00:00:09,013 16859 [sid:68B9,ip:79.19.30.120] INFO  session: [********-****-****-****-******ce80cd
2020-09-07 00:00:09,013 16859 [sid:68B9,ip:79.19.30.120] INFO  IN: [EmailAddress [address=k************@***.de],
    uid=null, session=********-****-****-****-******ce80cd]
2020-09-07 00:00:09,074 16920 [sid:68B9,ip:79.19.30.120] INFO  RequestLog 4bd67537bcf4 - '' '' -
    "DELETE https://server.foo/'' 204 () '' 60 millis ''
```

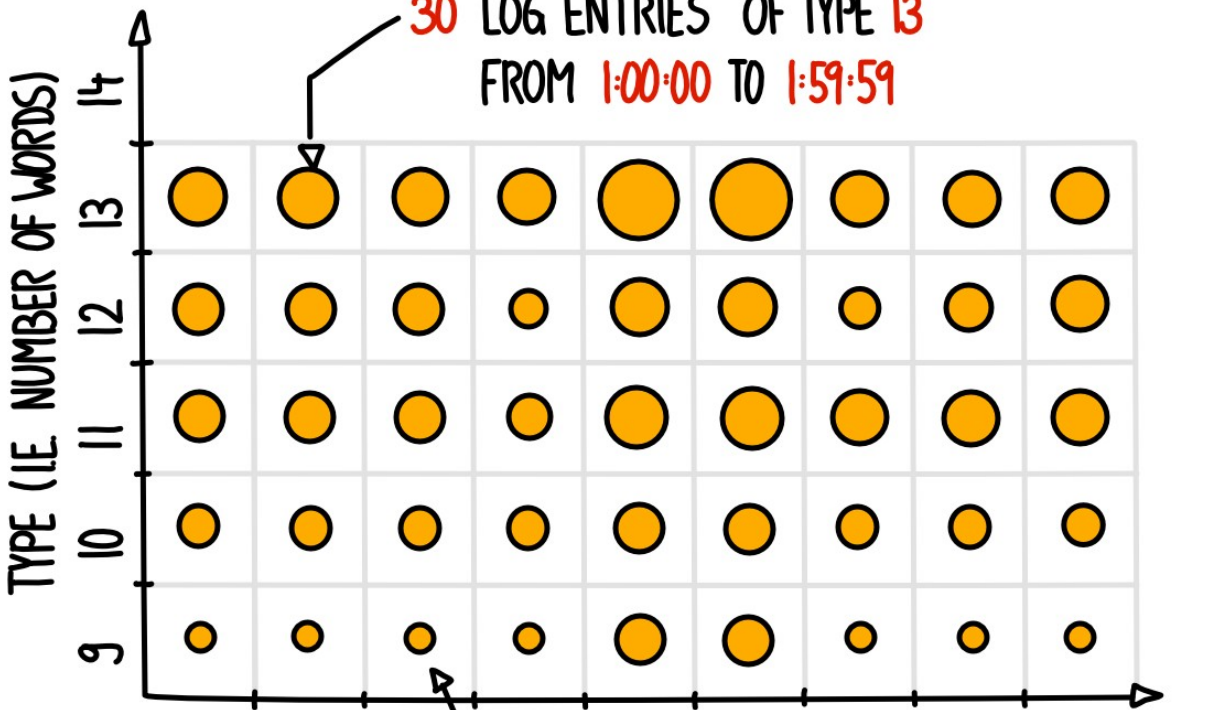
OUR GOAL

- VISUALIZE LOGFILES W/O PREPROCESSING
- SHOULD WORK FOR MOST LOGFILES

# VISUALIZE LOG FILES

APPROACH BASED ON PAPER:

"HISTOGRAM MATRIX: LOG FILE VISUALIZATION FOR ANOMALY DETECTION" 2007




1. GROUP LOG ENTRIES BY TIME
2. GROUP LOG ENTRIES BY TYPE
   - COUNT NUMBER OF WORDS
   - SPLIT BY SPACE

$$\tilde{N}_{h,t} = \frac{N_{h,t}}{\sum_t N_{h,t}}$$

# CONCLUSION

## SUMMARY

ATTACK VECTORS

BASICS OF MACHINE LEARNING

EXAMPLES:

- DETECT INTRUSION VIA SYSTEMS CALLS
- LOG FILE VISUALIZATION
- AUTOENCODER

## QUESTIONS / FEEDBACK / CONTACT / RESOURCES

HELLO@ETZOLD.IO

@ETZOLD10

GITHUB.COM/DANIEL-E

GITHUB.COM/DETECTR

## JUPYTER NOTEBOOKS / SLIDES

GITHUB.COM/DANIEL-E/2020-IT-SECURITY-SUMMIT