# Predicting Security Attacks in FOSS

## Why you want it and one way to do it

C.E. Budde R. Paramitha F. Massacci

Università di Trento (IT) & Vrije Universiteit (NL)

Vuln4Cast 2023 FIRST Technical Colloquium

# Talk overview

1. Introduction
2. Background
3. Forecast model
4. Conclusions

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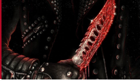
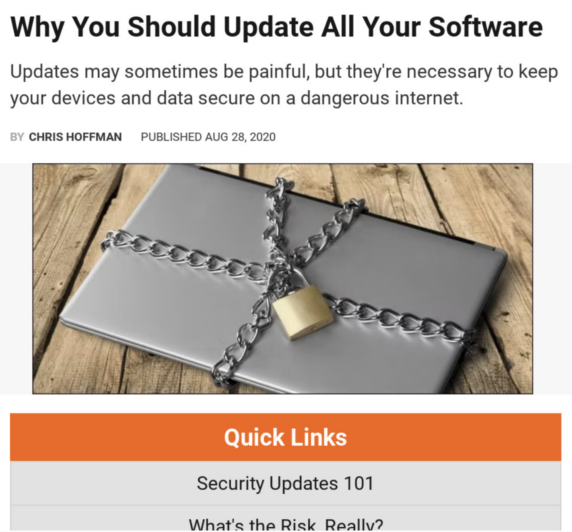
# The myth of the bleeding edge



© Carpenter Brut



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Updates may sometimes be painful, but they're necessary to keep your devices and data secure on a dangerous internet.

BY **CHRIS HOFFMAN** PUBLISHED AUG 28, 2020

**Quick Links**

Security Updates 101

What's the Risk, Really?

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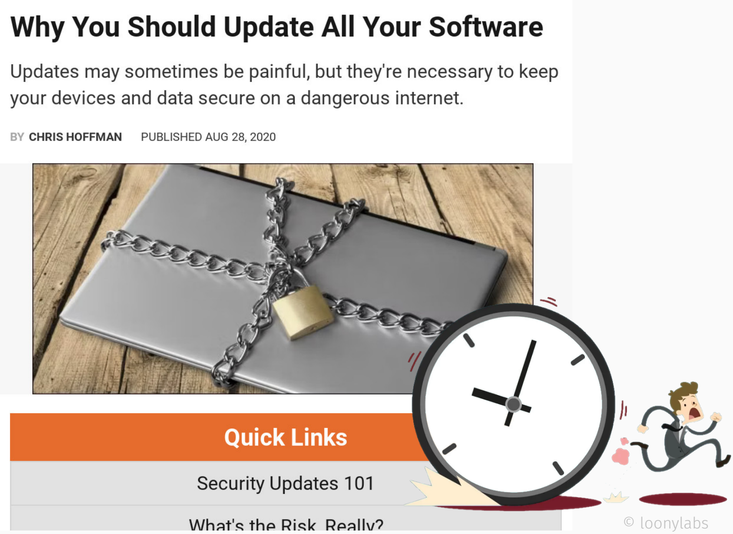

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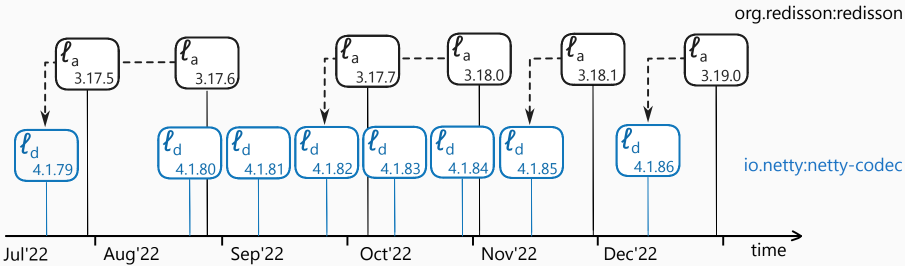

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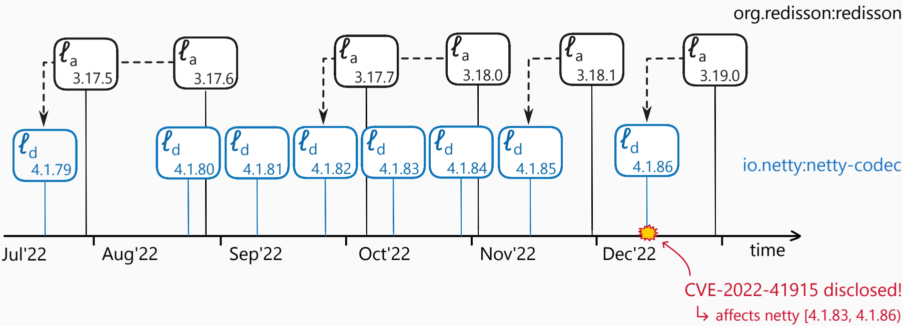

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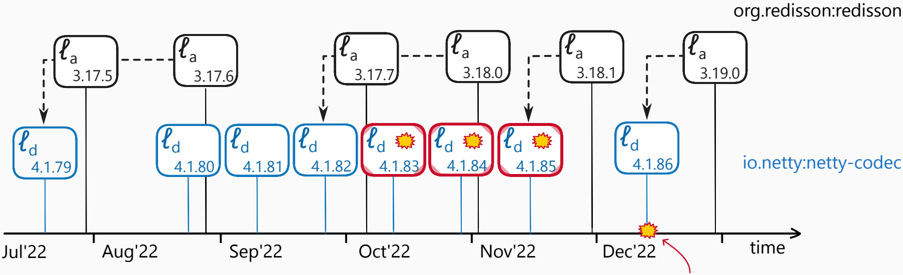

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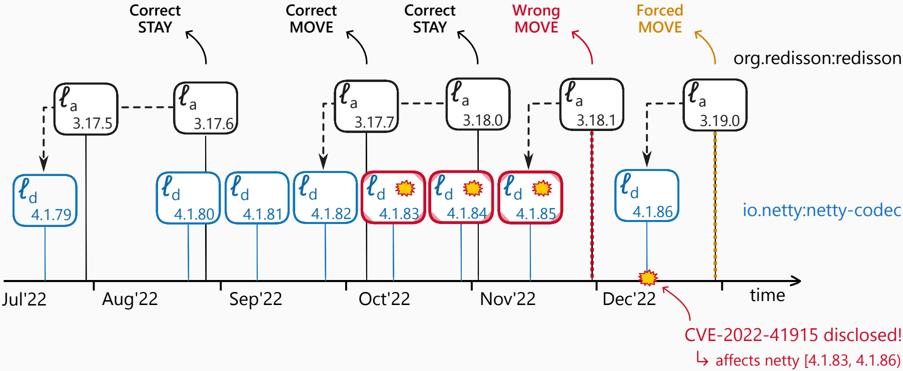

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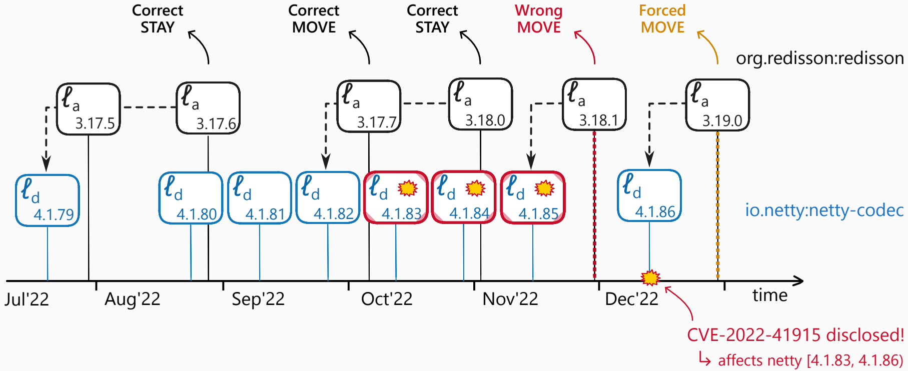

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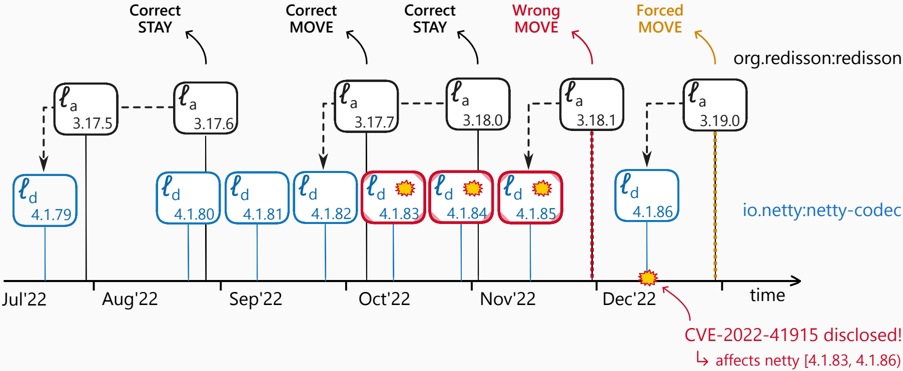

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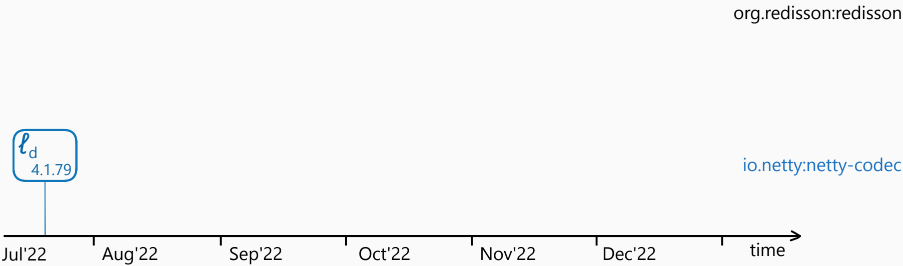

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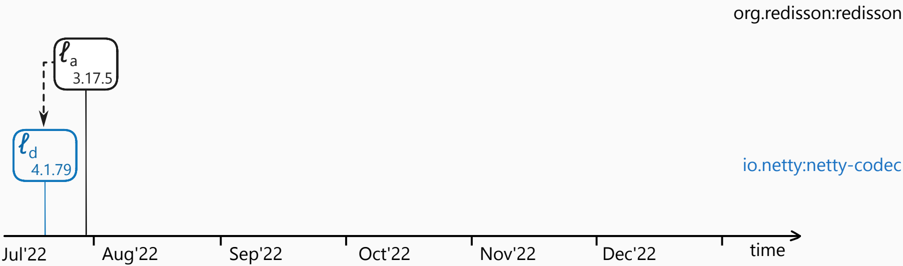

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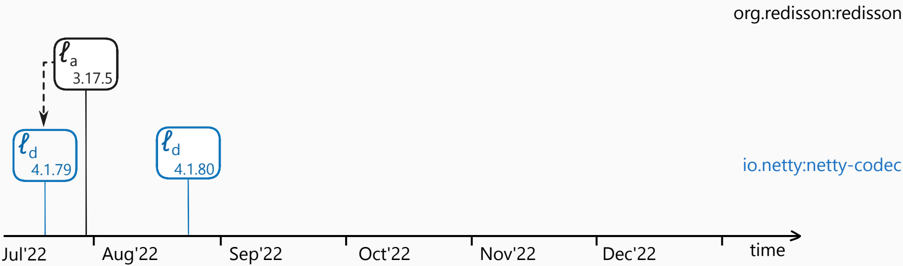

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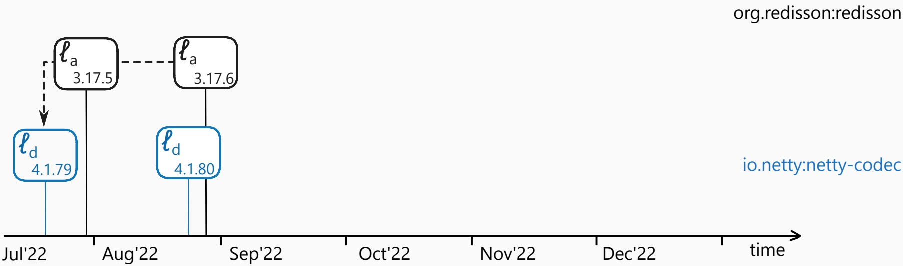

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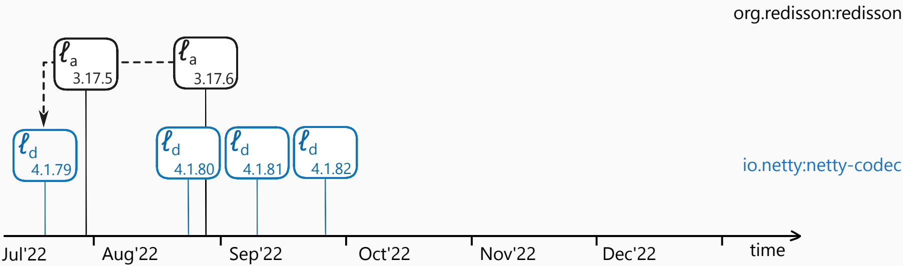

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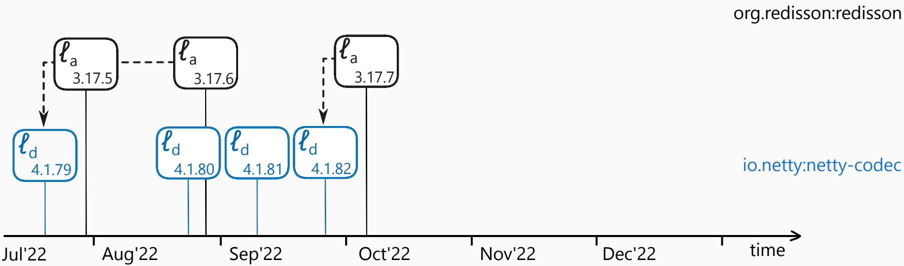

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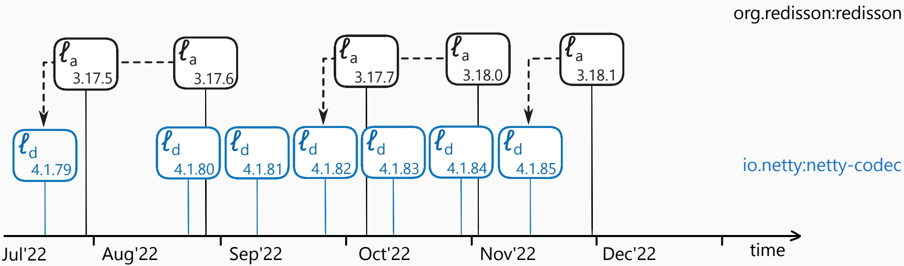

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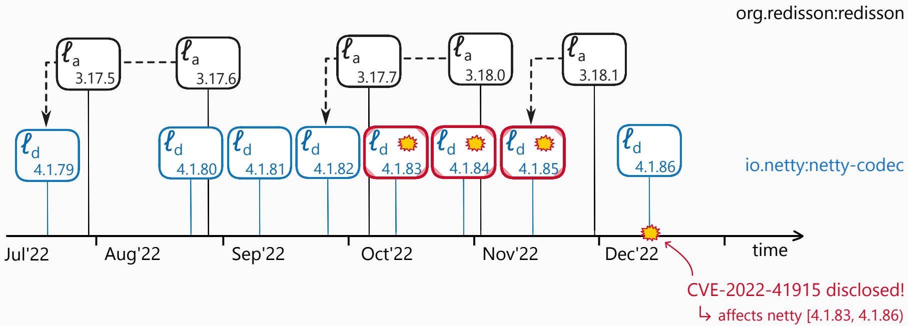

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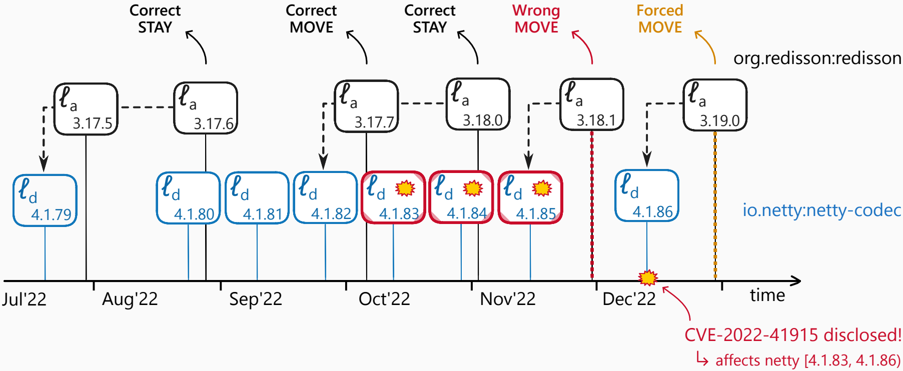

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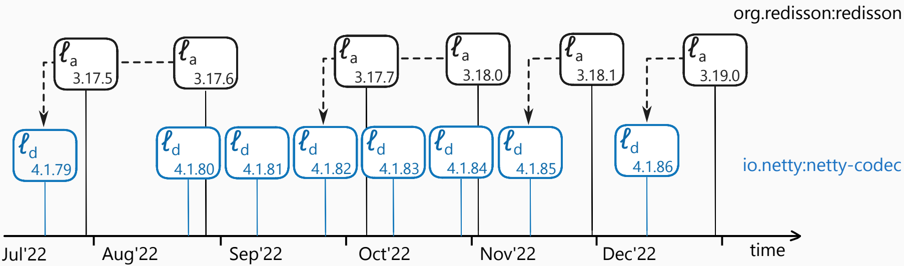

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- ▷ measurable software metrics

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| [23] | ✓ | | ✓ | ✓ | | | ✓ | ✓ | | | ✓ | ✓ | Java | 4 | |
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| [7] | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | | | ✓ | ✓ | C/C++, Java | 1 | |
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| [19] | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | | Java, Ruby, Python | 450 | |
| [17] | ✓ | | ✓ | ✓ | | ✓ | | ✓ | | ✓ | | | Java | 200 | |
| [26] | | ✓ | ✓ | | | | | | ✓ | | ✓ | ✓ | Agnostic | 9 | Time regression to predict vulnerabilities from NVD logs, but the models lack data from the security domain. |
| [10] | | ✓ | ✓ | | | | | | ✓ | | ✓ | ✓ | Agnostic | 25 | |
| [20] | | ✓ | ✓ | | | | | | ✓ | | ✓ | | Agnostic | 5 | |

Most works try to discover current vulnerabilities, not predict future ones

Most works disregard the code dependency tree

Most works do not consider time in their analyses

Disregarded security data

**Q2** $\Pr(\text{vuln.})$ as function of software metrics

**Q1** $\Pr(\text{vuln.})$ as function of time

**Q2** $\Pr(\text{vuln.})$ as function of software metrics

- ML & statistical analysis to correlate SE metrics to existent vulnerabilities

**Q1** $\Pr(\text{vuln.})$ as function of time

## State of the $\mathcal{ART}$ Models to predict vulnerabilities

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- ML & statistical analysis to correlate SE metrics to existent vulnerabilities
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- time-regression models on CVE publications (≈ FinTech)

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**We propose white-box model(s) to fill these gaps**

# Forecast model

1. Introduction

2. Background

3. Forecast model

4. Conclusions

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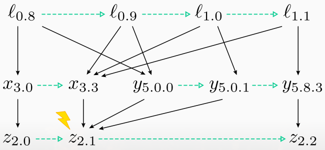
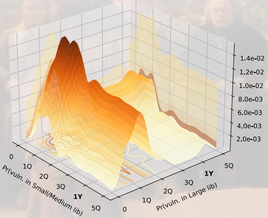
## Time Dependency Trees



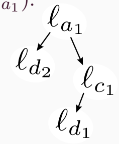


CVE root-lib PDFs

# Time Dependency Trees

Dependency Trees in time

$D(\ell_{a_1})$:



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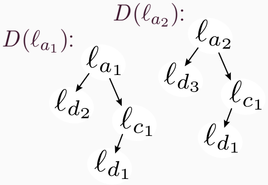

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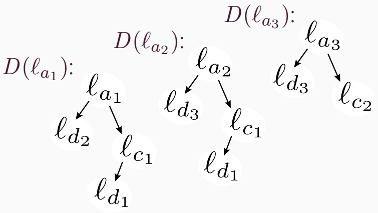

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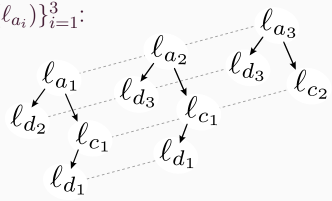
$\{D(\ell_{a_i})\}_{i=1}^{3}$:



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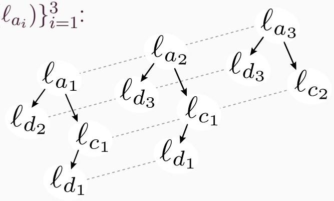

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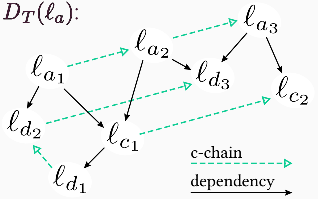

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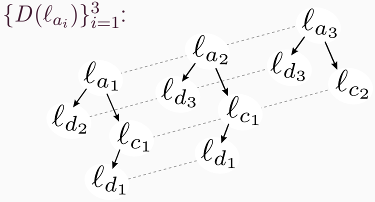

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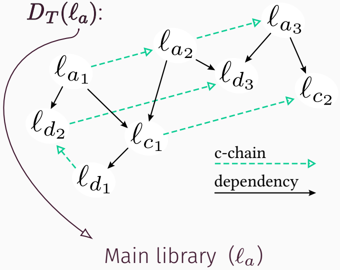

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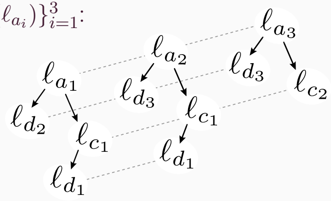

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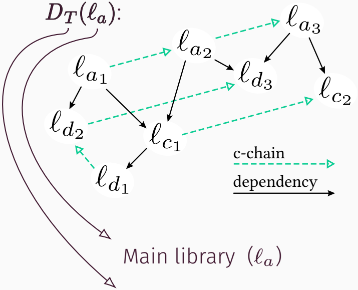

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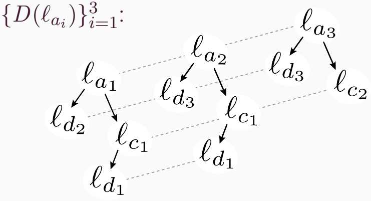

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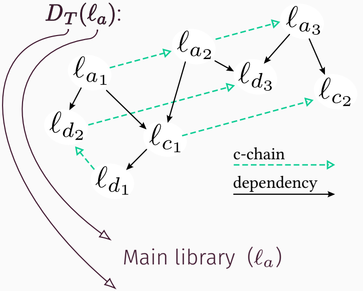

Main library $(\ell_a)$

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$D_t(\ell_a) = D(\ell_{a_1})$
for any time point $t \in T$
after the release of $\ell_{a_1}$ and
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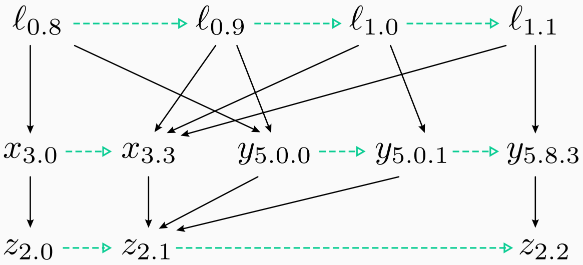
# SPoF in time and dependencies

My personal project uses $\ell_{1.0}$



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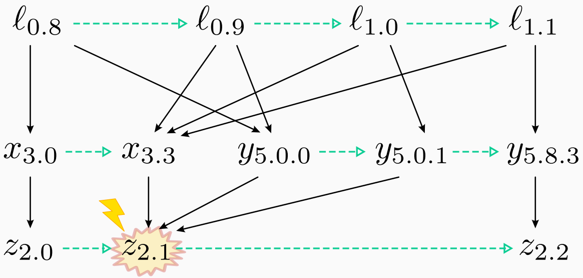

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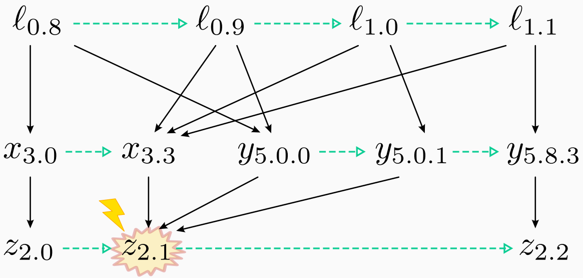

Should I downgrade to $\ell_{0.9}$ or upgrade to $\ell_{1.1}$?

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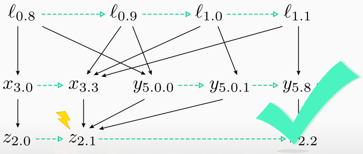

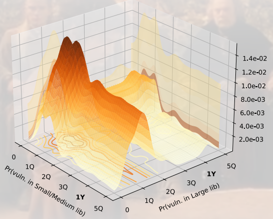

CVE root-lib PDFs

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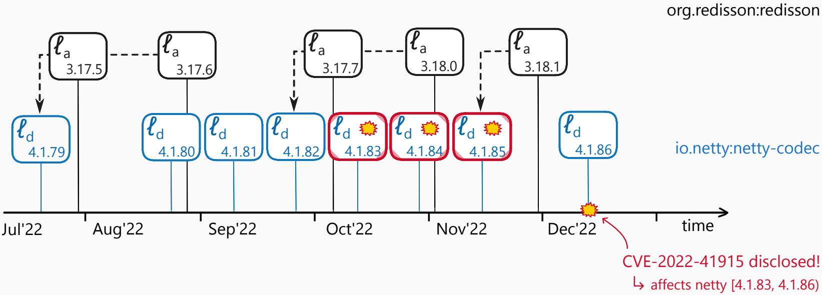

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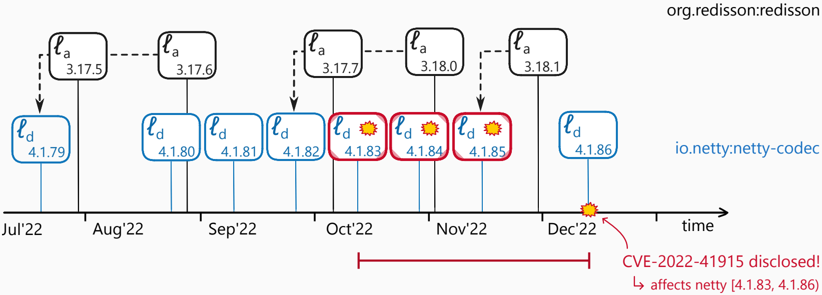

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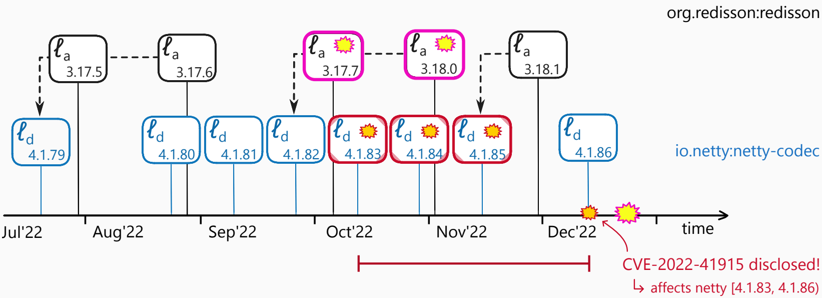

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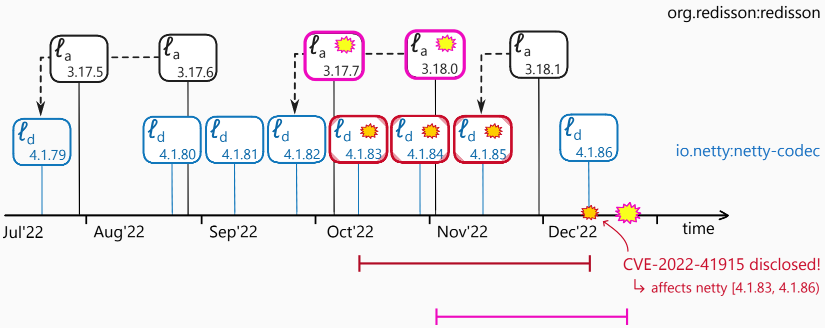

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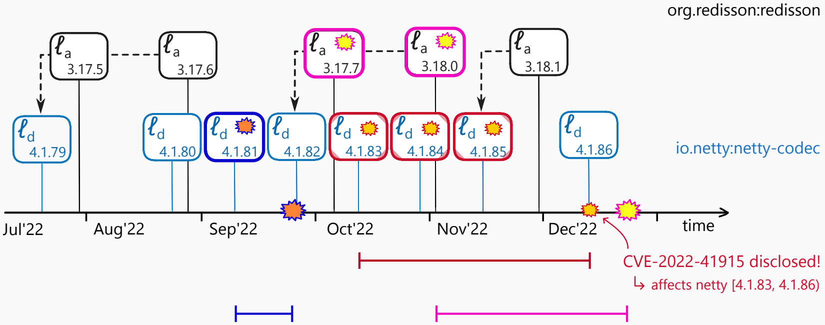

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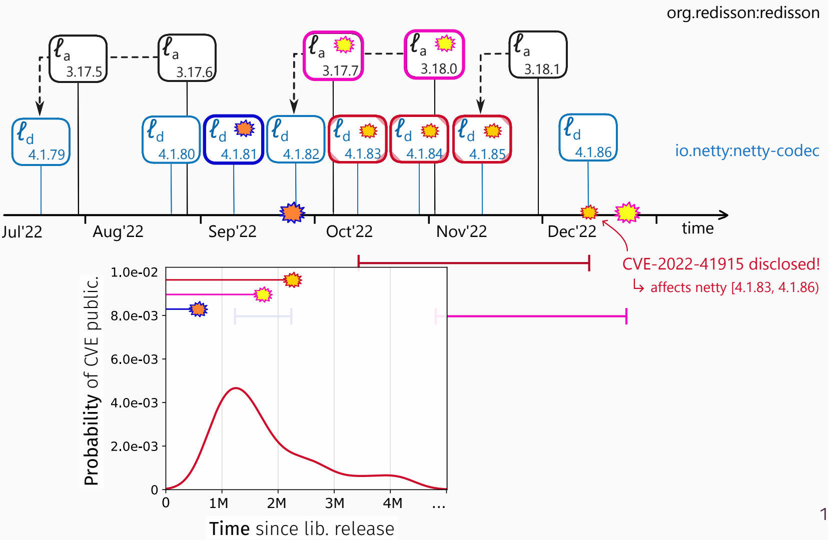

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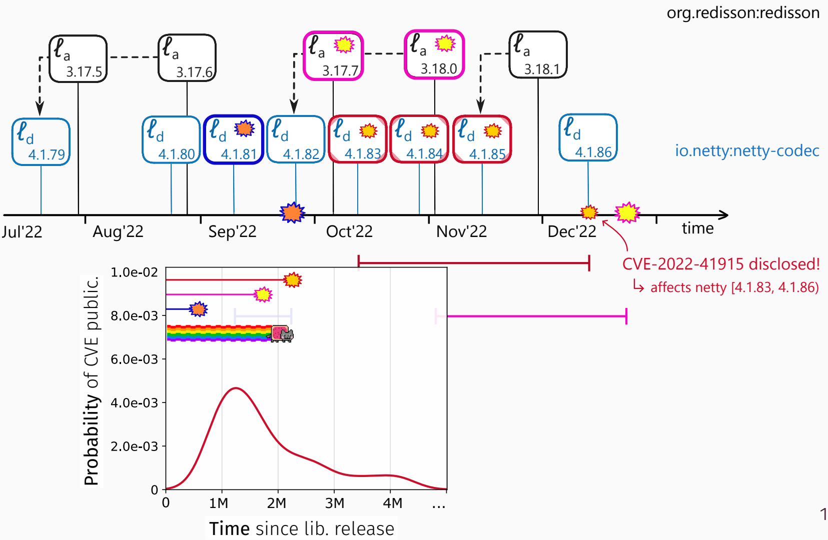

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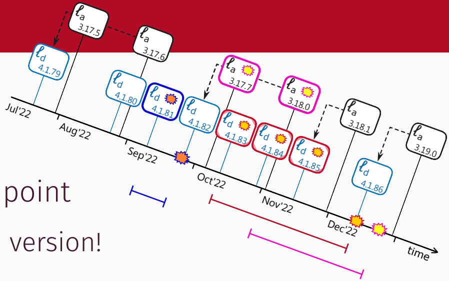

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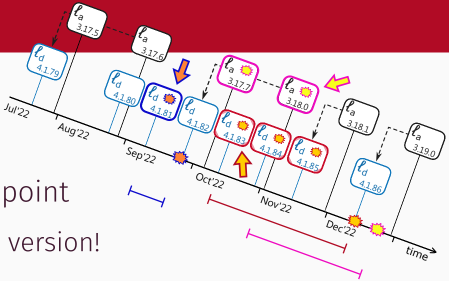

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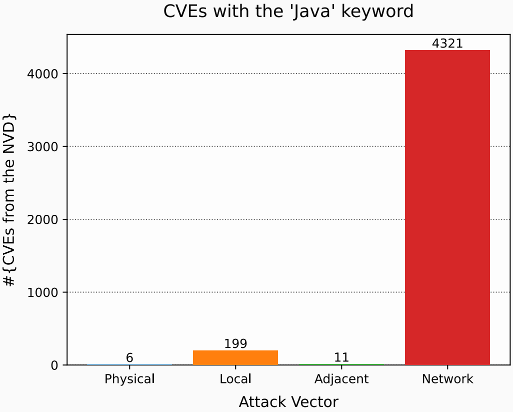
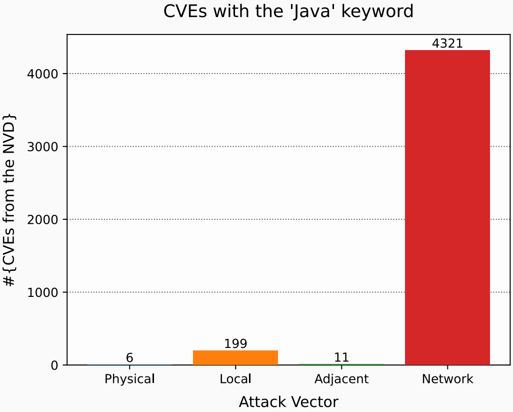


# Security-relevant code metrics

## Used in remote networks



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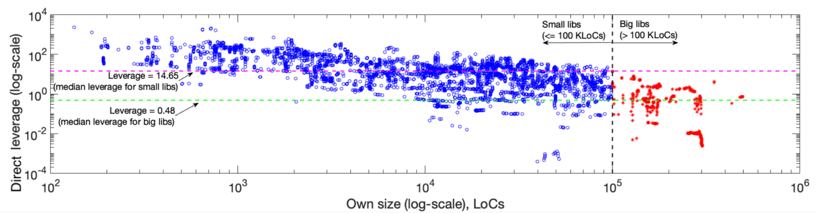

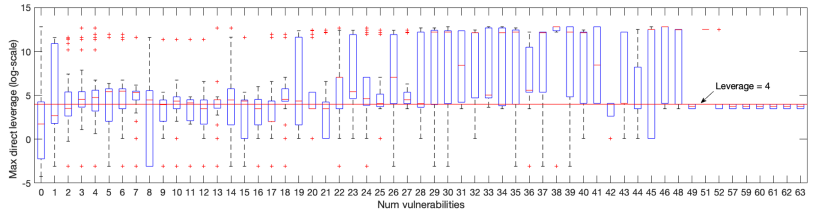

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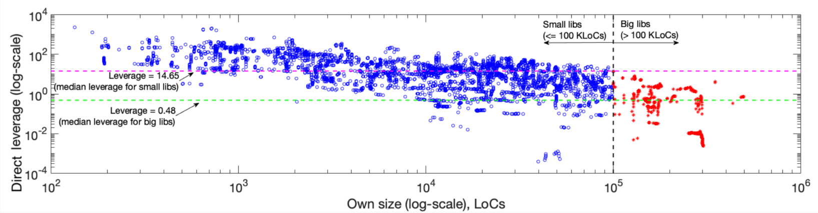
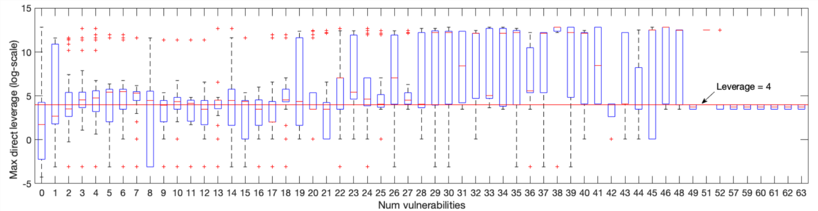
## (Own) Code size





# Security-relevant code metrics

| Work | Goal | | Data | | | | Method | | | Approach | | | Projects/Libs. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Disc. | Pred. | CVEs | Code | VCS | Dep. | Corr. | Clas. | T.Ser. | AH | SA | ML | Language | # | Purport |
| [4] | ✓ | | | ✓ | | | | ✓ | | | | ✓ | C | 3 | Find vulnerabilities regardless of existent logs such as CVEs (although CWEs may be used). This includes formal methods and static/dynamic code analysis. |
| [2] | ✓ | | | | ✓ | | ✓ | ✓ | | | | ✓ | PHP | 3 | |
| [16] | ✓ | | | ✓ | | | ✓ | ✓ | | | ✓ | ✓ | Java | 4 | |
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Own-code size

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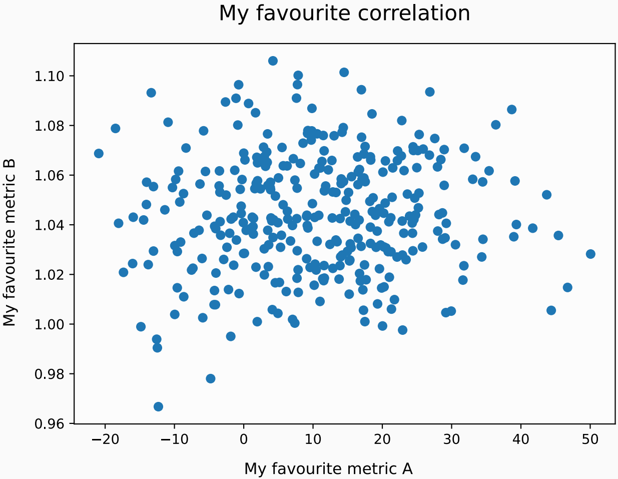

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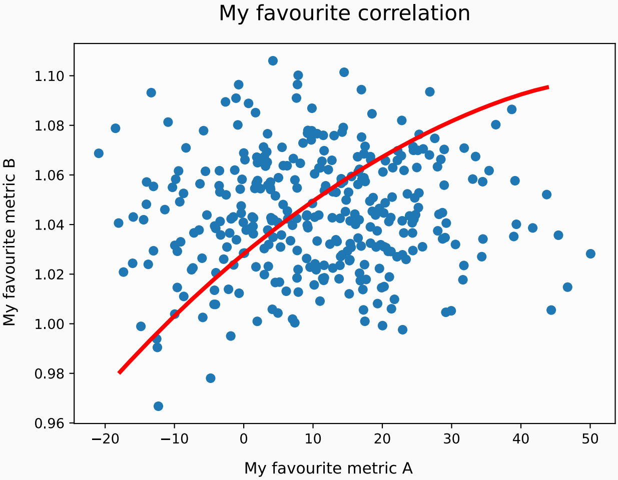

Own-code size

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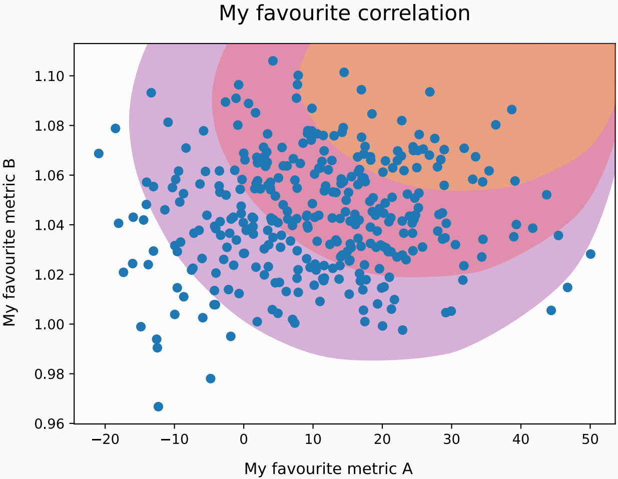

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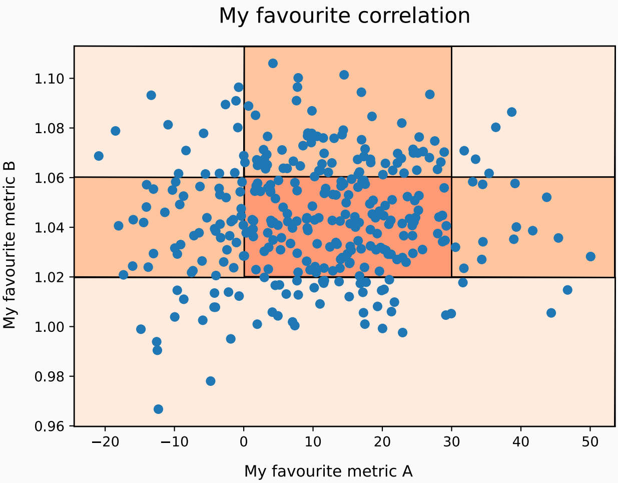

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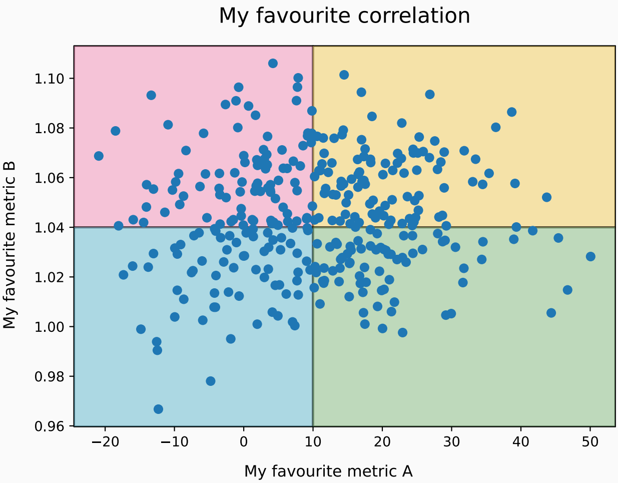

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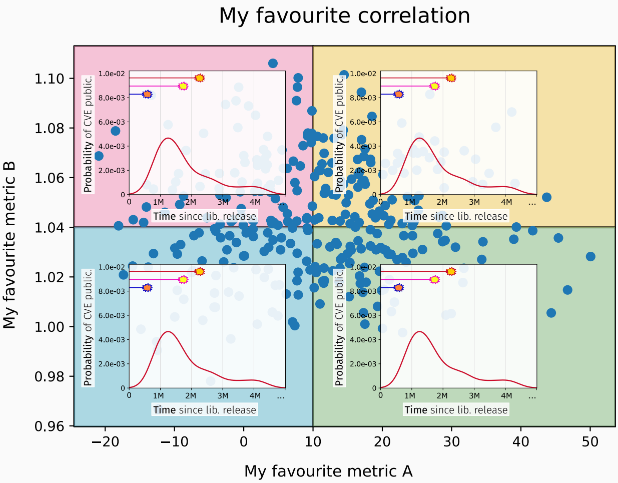

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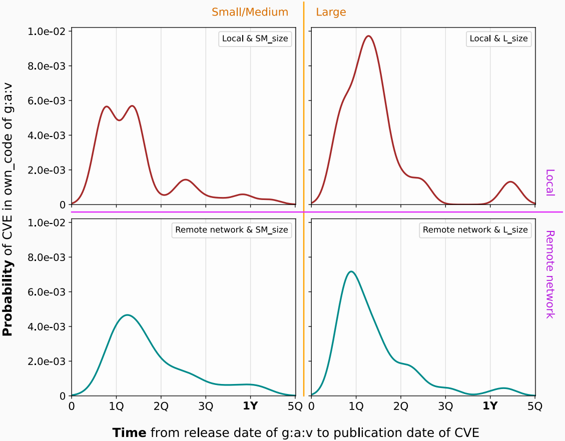
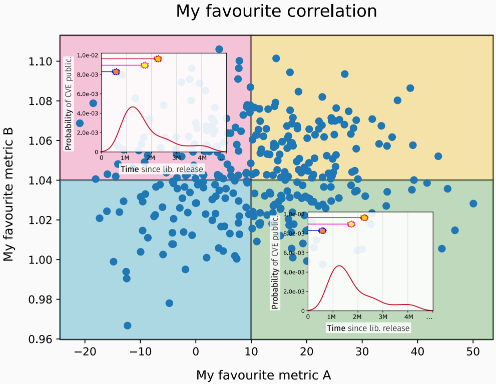


Own-code size

# On overfitting and rare events



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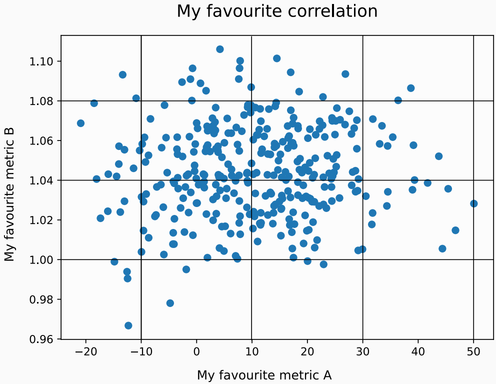

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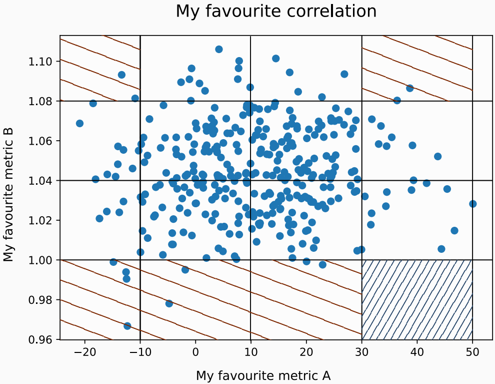

# On overfitting and rare events

- Count each CVE as one data point
- Discriminate per development environment
- Discriminate per library type

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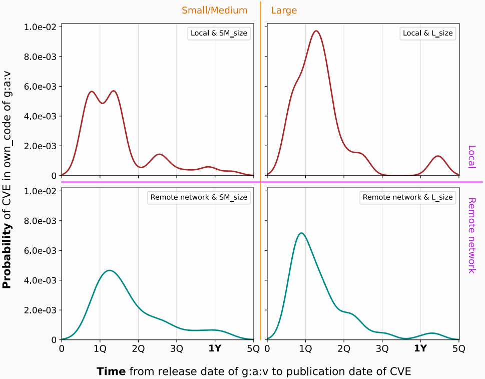
- Count each CVE as one data point
- Discriminate per development environment
- Discriminate per library type
- Clusterisation mustn't be too thin
  - few divisions per metric-dimension
  - few metric-dimensions

# Enough!

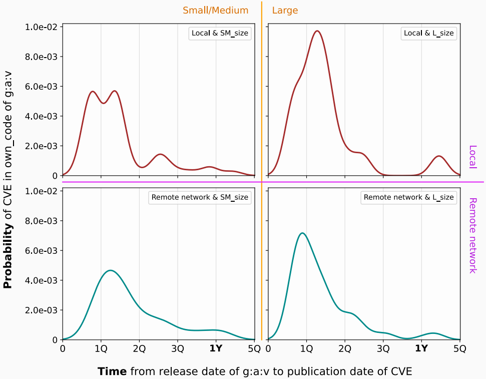
Gimme results

# Here ya go



Small/Medium
Large
Local & SM_size
Local & L_size
Remote network & SM_size
Remote network & L_size
Local
Remote network
Probability of CVE in own_code of g:a:v
Time from release date of g:a:v to publication date of CVE
1.0e-02
8.0e-03
6.0e-03
4.0e-03
2.0e-03
0
0
1Q
2Q
3Q
1Y
5Q

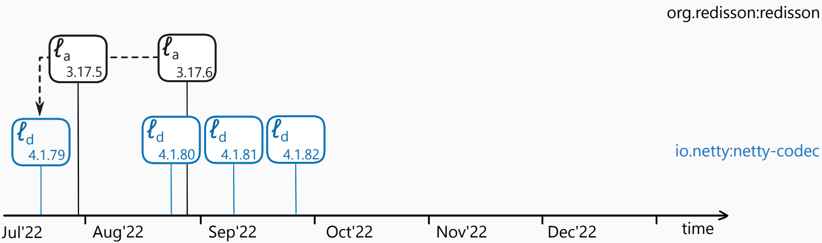
# Here ya go



**Q1** $\Pr(\text{vuln.})$ as function of time

**Q2** $\Pr(\text{vuln.})$ as function of software metrics

# Survival analysis on library update



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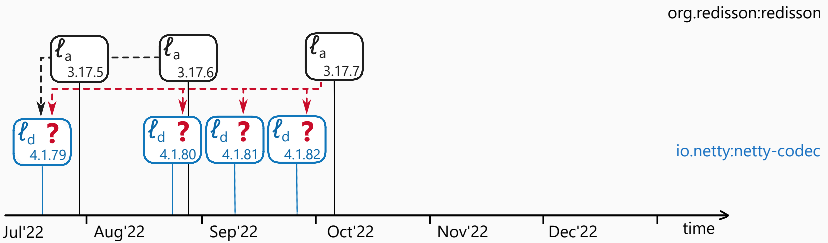

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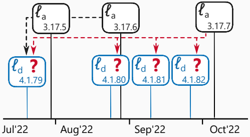

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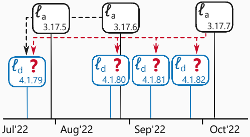

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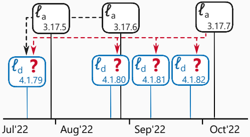

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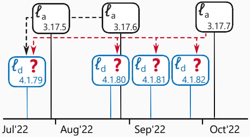

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vuln. in $\ell_A$ before change vuln. in $\ell_B$ after change

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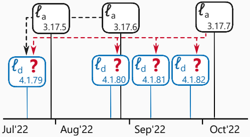

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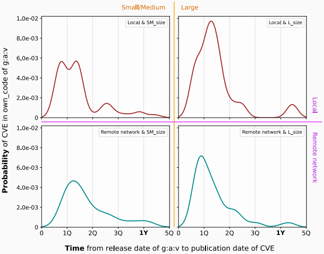

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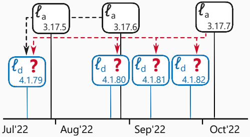

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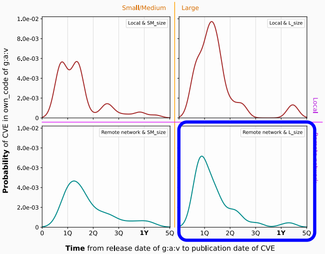

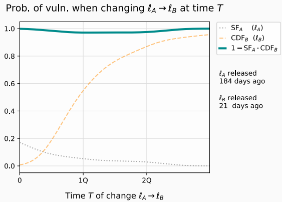

$t_A = 184$ days
$t_B = 21$ days

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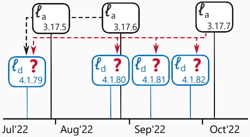

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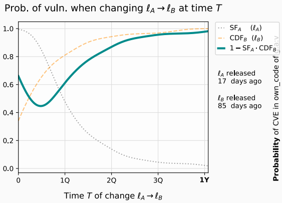
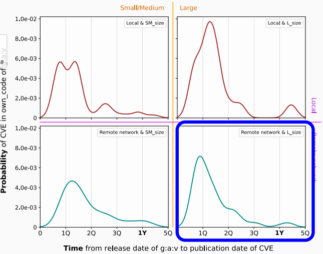
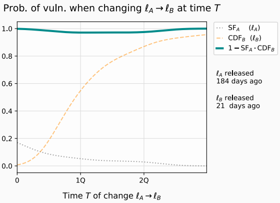


$t_A$ = 17 days
$t_B$ = 85 days





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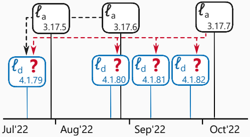

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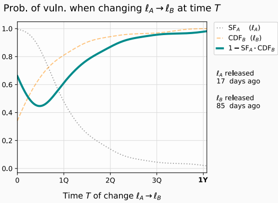

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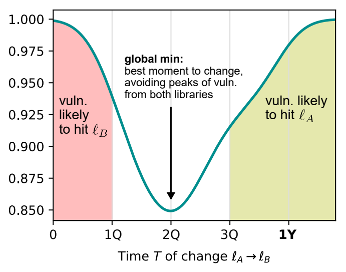

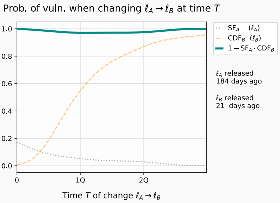

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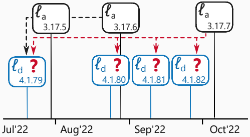

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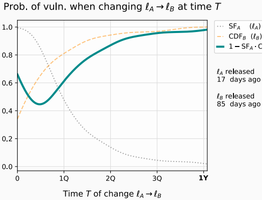

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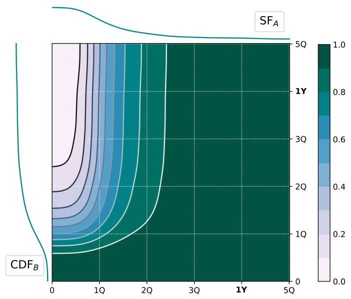

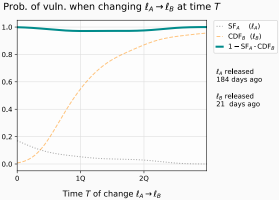

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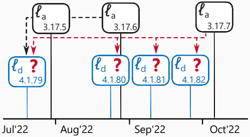

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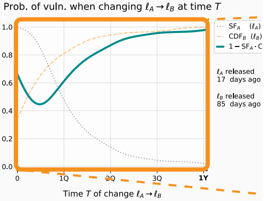

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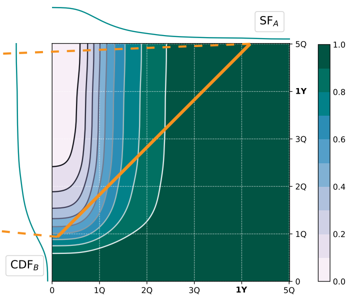

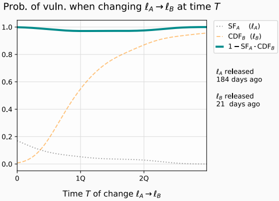

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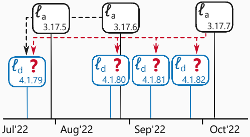

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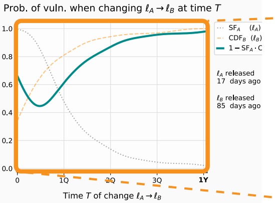

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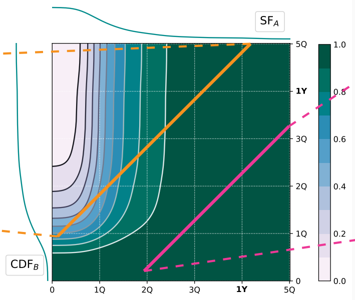

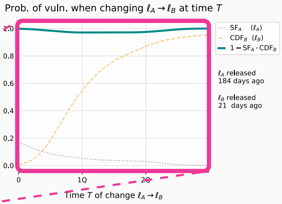

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**Q:** $\mathsf{Pr}_{A,B}(t) =$ probability of vuln. in $\ell_A$ or $\ell_B$ before $t$

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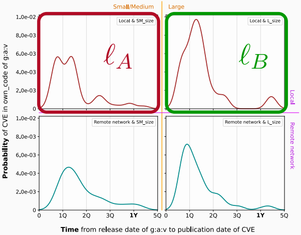

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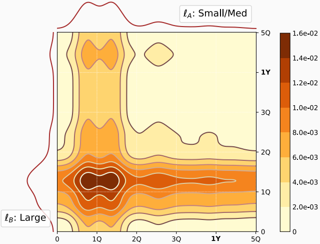

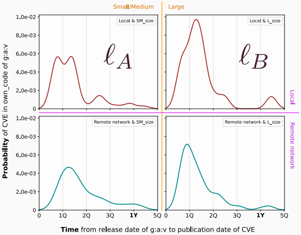

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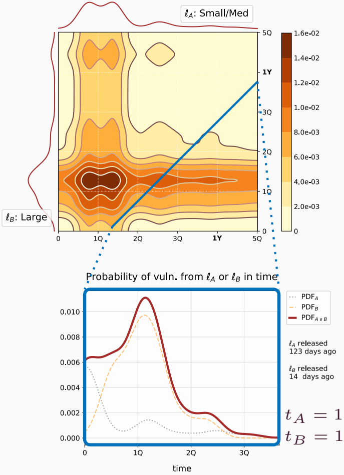
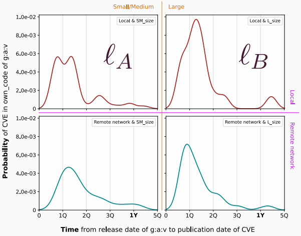


$t_A$ = 123 days

$t_B$ = 14 days



# Vulnerabilities from any dependency

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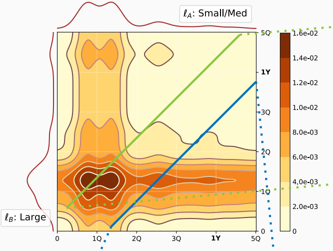
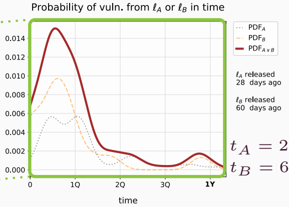
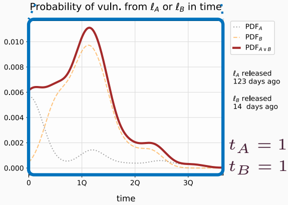




$t_A = 28$ days

$t_B = 60$ days



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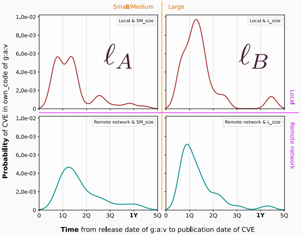

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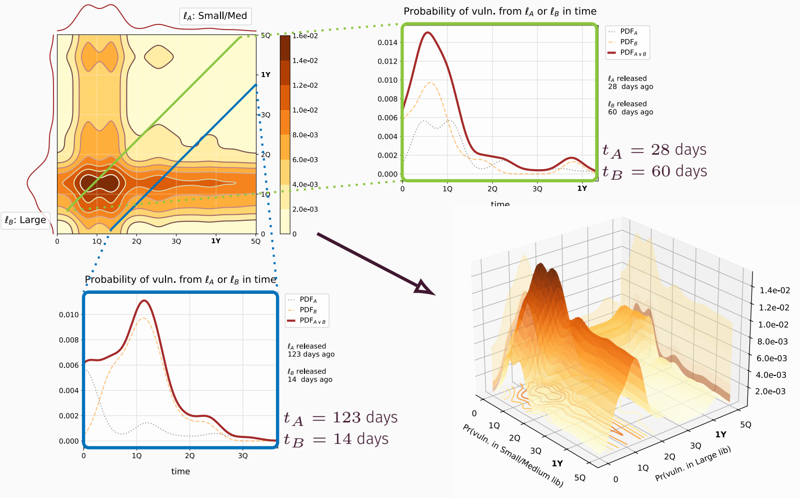

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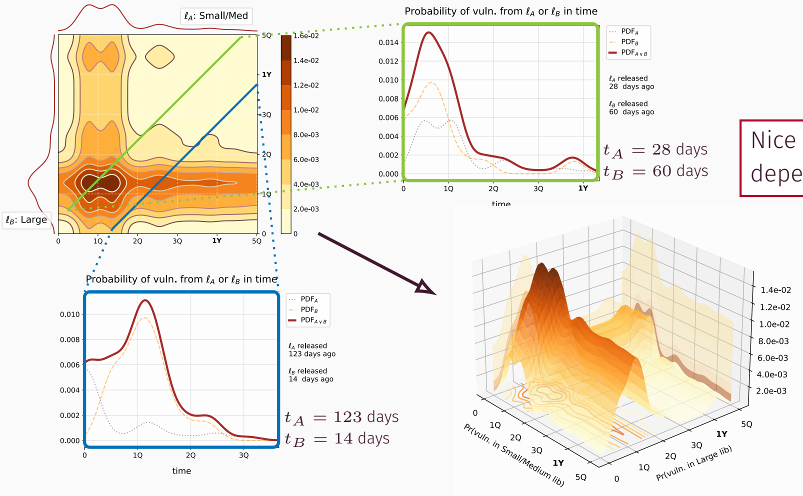

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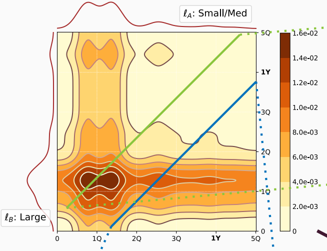

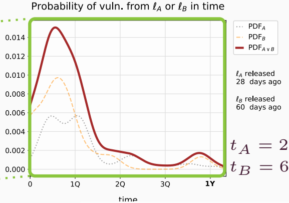

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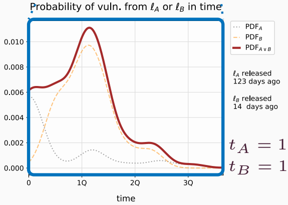
**I have 2000**



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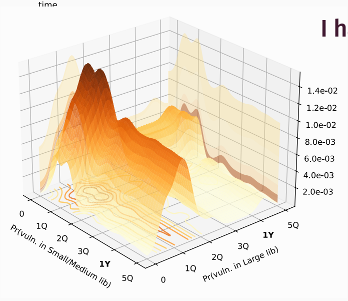

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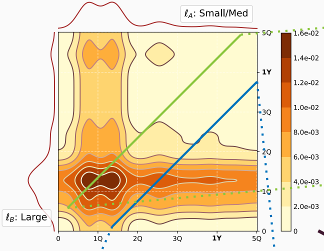

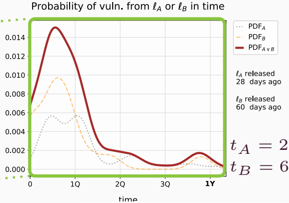

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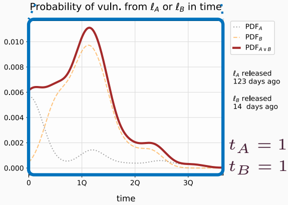

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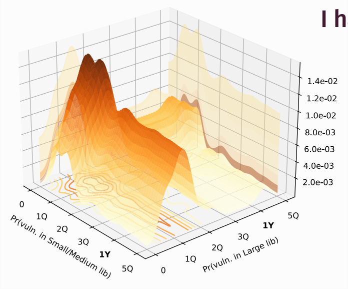

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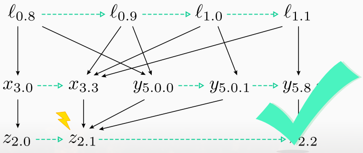
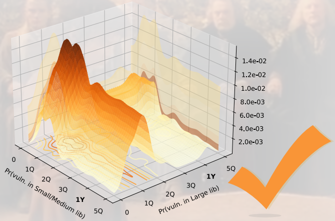
**TDTs!**

# Forecast model

1. Introduction
2. Background
3. Forecast model
4. Conclusions

Time Dependency Trees





CVE root-lib PDFs

# Conclusions

1. Introduction
2. Background
3. Forecast model
4. Conclusions

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- Time Dependency Trees

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  - Base information for probability forecasting

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‸ to be

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- c-chains polution by CVE

Questions?

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# Predicting Security Attacks in FOSS

## Why you want it and one way to do it

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