Modelling Risk in Open-Source Software

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Introduction

- → Popularity of Open-Source Software has been increasing
 - ◆ 3.6 million repos depend on the top 50 open-source projects
- → Comes with the risk of software vulnerabilities
 - Attackers can exploit these
- → Prediction of risk can be used to explore risk
 - ◆ Software metrics
 - Project Activity
 - ◆ Vulnerability Data

Research Question

Can we provide developers with an effective risk measure when choosing between multiple open-source components?

Key Terms

- → Maven
 - Open-source build automation & project management tool
- → Time series analysis
 - Fitted model based on past data can predict future values
- → ARIMA
 - Autoregressive integrated moving average
 - p, d, q parameters
- → AutoARIMA
 - Tests parameter combinations to determine the best model

Background Research

Vulnerability Propagation

- → Only 1.2% directly use vulnerable code
- → Small packages can affect 375, 607 packages in the Maven ecosystem
 - jackson-databind, netty-codec-http
 - ◆ CVEs can affect a large number of projects
- → The more dependencies the more complex it is to locate where the project pulls in vulnerable code

Project Metadata Analysis

- → Project activity level is an indicator of survival
 - ♦ Number of commits, time-to-fix
 - ◆ Long-time Contributors
- → Less than 50% of abandoned projects find new contributors
- → Standard measurement for commits is:
 - Number of commits per month

Vulnerability CVE Data Analysis

- → Predicting number of vulnerabilities per month is useful
- → ARIMA is a very popular method of prediction
 - Seasonality not a factor
- → Datasets from the NVD were used in every study we analysed
 - Prediction of CVEs
- → Most models fall flat at the three month mark

Case Studies

Log4j Vulnerability

- → Discovered in November 2021 in popular logging library
- → Gateway to gain control of the machine
- Many projects unaware they were affected

Heartbleed Vulnerability

- → Discovered in April 2014 in popular cryptography library
- → Receive private information after crafting similar messages
- Many servers unaware they were affected

Methodology

Data & Dependencies

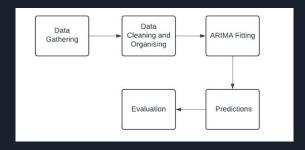
- → Different GitHub projects to test the algorithm
- → GitHub API for project activity
- → NVD API for vulnerability

 Data

- Each Maven Dependency as a node
- → NetworkX graph
- → Keywords and libraries extracted for prediction
- → Colour-coded

Data Source	Purpose	Type	
GitHub projects	Find Dependencies	Maven-dependency trees	
GitHub API	Project Meta-data	API CVE API	
NVD API	Vulnerability Prediction		

Predictions



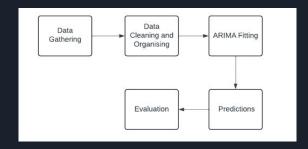
Project Activity

- → GitHub API
 - ◆ All available data gathered
- → Commits, average time-to-fix issues or both
- → AutoARIMA model
- → Predicted value for the next month returned

Hamcrest Dependency in Maven Project: org.hamcrest:hamcrest-core:jar:1.3:test

Keyword for Hamcrest Dependency: hamcrest-core

Predictions



Vulnerabilities

- → NVD API
 - Call made for each keyword
- → Number of vulnerabilities per month
- → AutoARIMA model
- → Predicted value for the next month returned

```
JUnit4 Dependency in Maven Project:
junit:junit:jar:4.11:test

Array of Keywords in JUnit Dependency:
['junit', 'junit4', 'junit jar']
```

Risk Calculations

```
projectActivityScore = (x/numDaysToFixIssues)*10
```

```
projectActivityScore = (numCommits/x) * 10
```

vulnerabilityScore = (x/vulsCountPerMonth) * 10

$$overallScore = (projectActivityScore + \\ vulnerabilityScore)/2$$

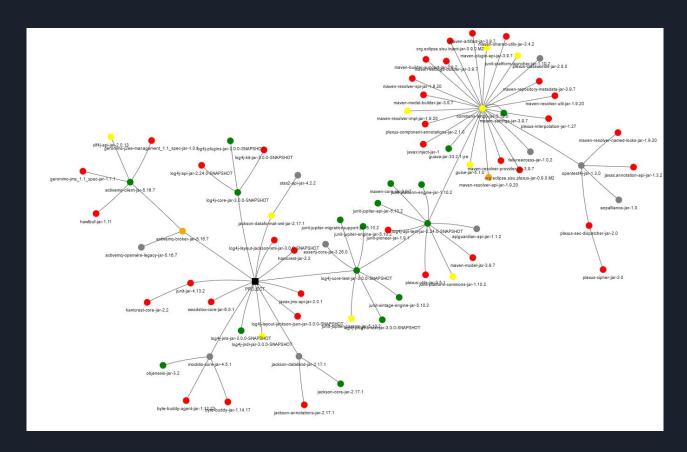
- → User-decided acceptable levels
- → Options for project activity score
- → Combination of project activity and vulnerability for overall score

Score	Risk Level	
<0	Not Enough Data	
0 - 2.5	Low Risk	
2.5-5	Medium Risk	
5-7.5	High Risk	
>7.5	Severe Risk	

Results

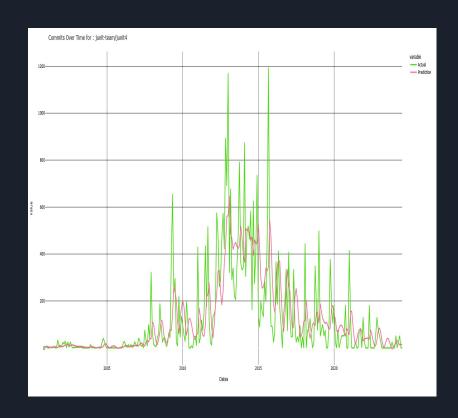
Example Final Graph





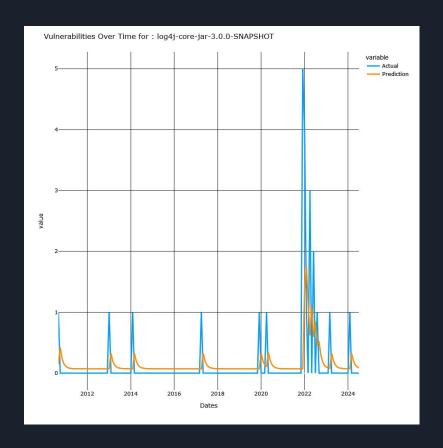
Example Graph of Project Activity Model

- → JUnit4 commits over time
- → Activity has declined in recent years
- → 2012 to 2017 were high-commit years
 - ◆ At its peak over 200 commits per month
- → Fitted values are fairly accurate as can be seen in the graph
- → Predicted value for the next month
 - **♦** 10.9951



Example Graph of Vulnerability Data Model

- → Log4j vulnerabilities over time
- → Many were released in 2021
 - 5 released in one month
- Reasonably accurate fitted values in subsequent months
- → Predicted value for the next month
 - 0.07898



Evaluations

Prediction	MAE	RMSE
Commits per month	123.18	213.96
Vulnerabilities per month	0.145	0.476

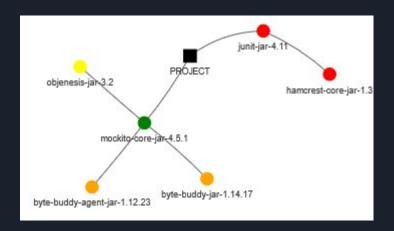
- → Log4j sample project
- → Commonly used metrics
 - Mean Absolute Error (MAE)
 - Root Mean Squared Error (RMSE)
- → Commits have larger standard deviation
 - **♦** 152.79
- → Vulnerabilities have lower standard deviation
 - **♦** 0.432

Technical Challenges

- → Graphing dependencies and dependencies of dependencies
- → Choosing of ARIMA parameters
 - Decided on AutoARIMA
 - ◆ PACF and ACF graphs
 - ◆ Differencing data until ADF test below 0.05
- → Connecting dependencies to GitHub URLs
 - Done using a mapping file

Tool Uses

- → Comparing similar dependencies
 - ◆ JUnit vs Mockito
- → Exploring risk in current dependencies
 - Finding risky modules



Student Contribution

Róisín

- → Gitlab setup + Assigning Issues
- → Literature Review
 - ◆ Writing + read 42 papers
- → Software
 - ♦ All code
- → Practicum Paper
 - All writing

Sneha

- → Read around 15 papers
- → Attempted to create graphs
- → Attempted to create keyword function.

Conclusion

- → Growing reliance on OSS
 - Challenges regarding security
- → Better overview of dependency risk
- → Focused on Maven dependency trees
- Compromised on accuracy to predict many dependencies
- → Tool could aid developers in
 - Choosing less risky modules
 - Discovering already used risky dependencies

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Thank You For Listening!

Questions?