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

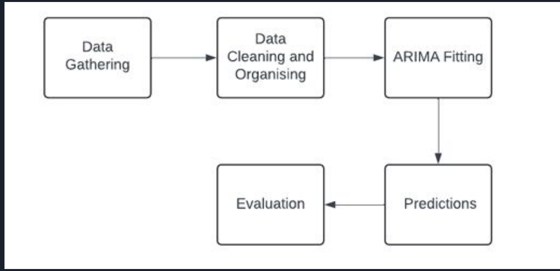
Methodology

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
NVD API	Vulnerability Prediction	CVE API

Predictions



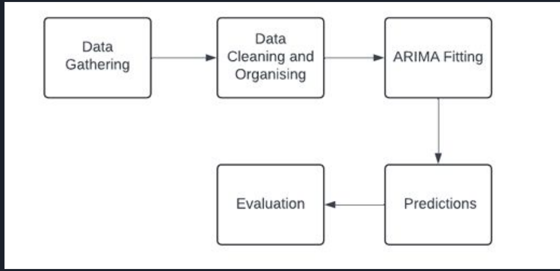
Project Activity

- ➔ 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

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

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

$$vulnerabilityScore = (x/vulsCountPerMonth) * 10$$

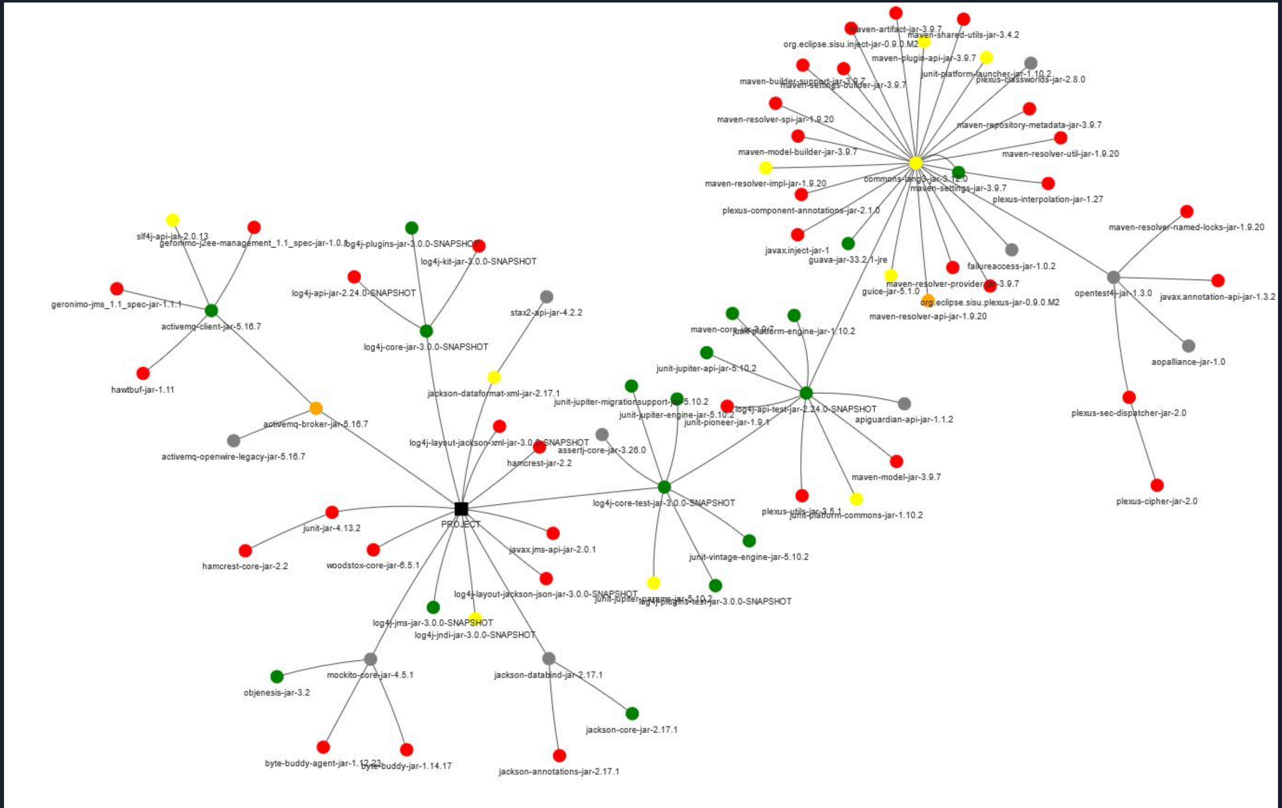
$$overallScore = (projectActivityScore + vulnerabilityScore)/2$$

- ➔ 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

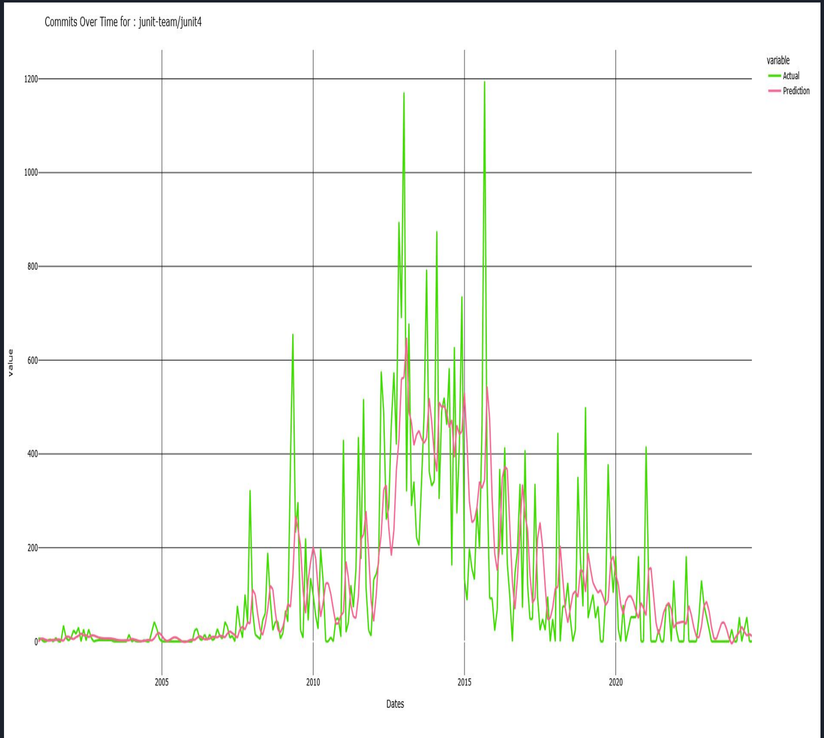
Results

Example Final Graph



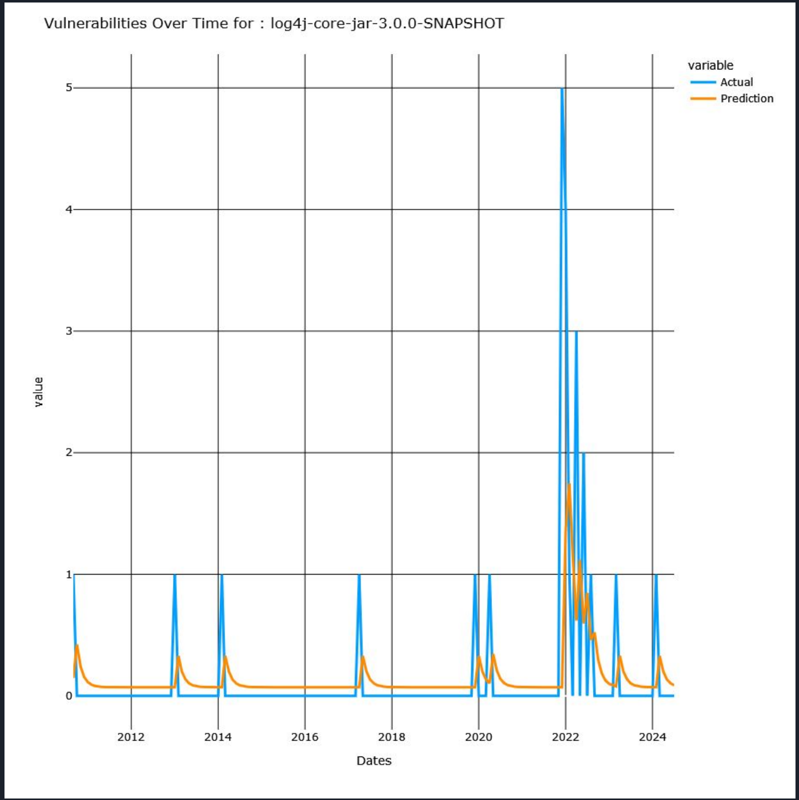
Example Graph of Project Activity Model

- ➔ 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

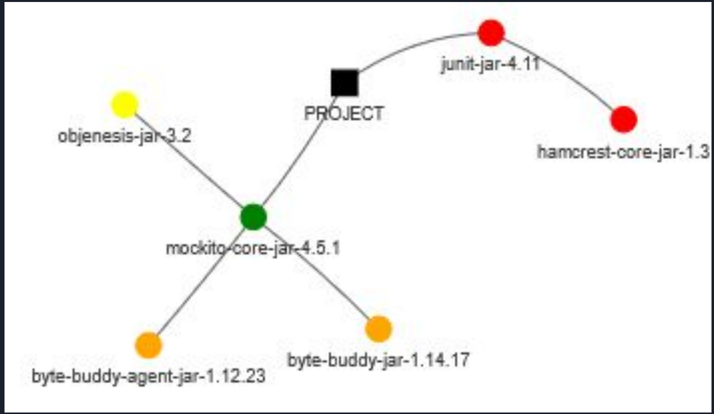
- ➔ Log4j sample project
- ➔ Commonly used metrics
  - ◆ Mean Absolute Error (MAE)
  - ◆ Root Mean Squared Error (RMSE)
- ➔ Commits have larger standard deviation
  - ◆ 152.79
- ➔ Vulnerabilities have lower standard deviation
  - ◆ 0.432

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?