An Analysis of Risk in Open-Source Project Dependencies

Róisín Ní Bhriain - 23269640
Sneha Dechamma Mallengada Suresh - 23262168
Course: MCM Computing
Supervisor: Darragh O'Brien

Introduction

- Popularity of Open Source Software has shown a steady increase over time
  - 3.6 million repos depend on the top 50 open-source projects
- The use comes with the risk of software vulnerabilities
  - Attackers can exploit these
- Prediction of risk is important for this
  - Software metrics
  - Project Activity
  - Vulnerability Data

Research Questions

Question 1:

Are there feature combinations that can be made from risk prediction methods that could provide developers with a more effective risk measure that allows them to minimise risk when choosing between multiple candidate open-source components?

Question 2:

Can a visual dependency tree be created for a project consisting of colour-coded nodes based on the predicted risks?

Background Research

Vulnerability Propagation

- Only 1.2% directly use vulnerable code
- Small packages can affect many packages in the Maven ecosystem
  - CVEs can affect a large number of projects
- The more dependencies the more complex it is to find vulnerabilities in dependencies

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 also important
- 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 Gathering

- ➔ 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

TABLE I
LIST OF SOURCES USED

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

Predictions

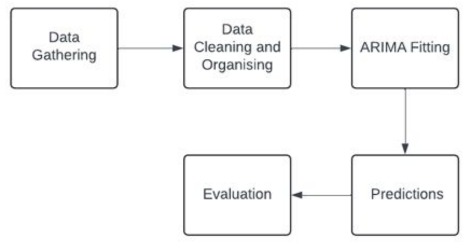


Fig. 1. The Time Series Pipeline.

Project Activity

- ➔ GitHub API
  - ◆ All available data gathered
- ➔ Commits, average time-to-fix issues or both
- ➔ AutoARIMA prediction
- ➔ Final fitted value returned

Vulnerabilities

- ➔ NVD API
  - ◆ Call made for each keyword
- ➔ Number of vulnerabilities per month
- ➔ AutoARIMA Prediction
- ➔ Final fitted value returned

Risk Calculations

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

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

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

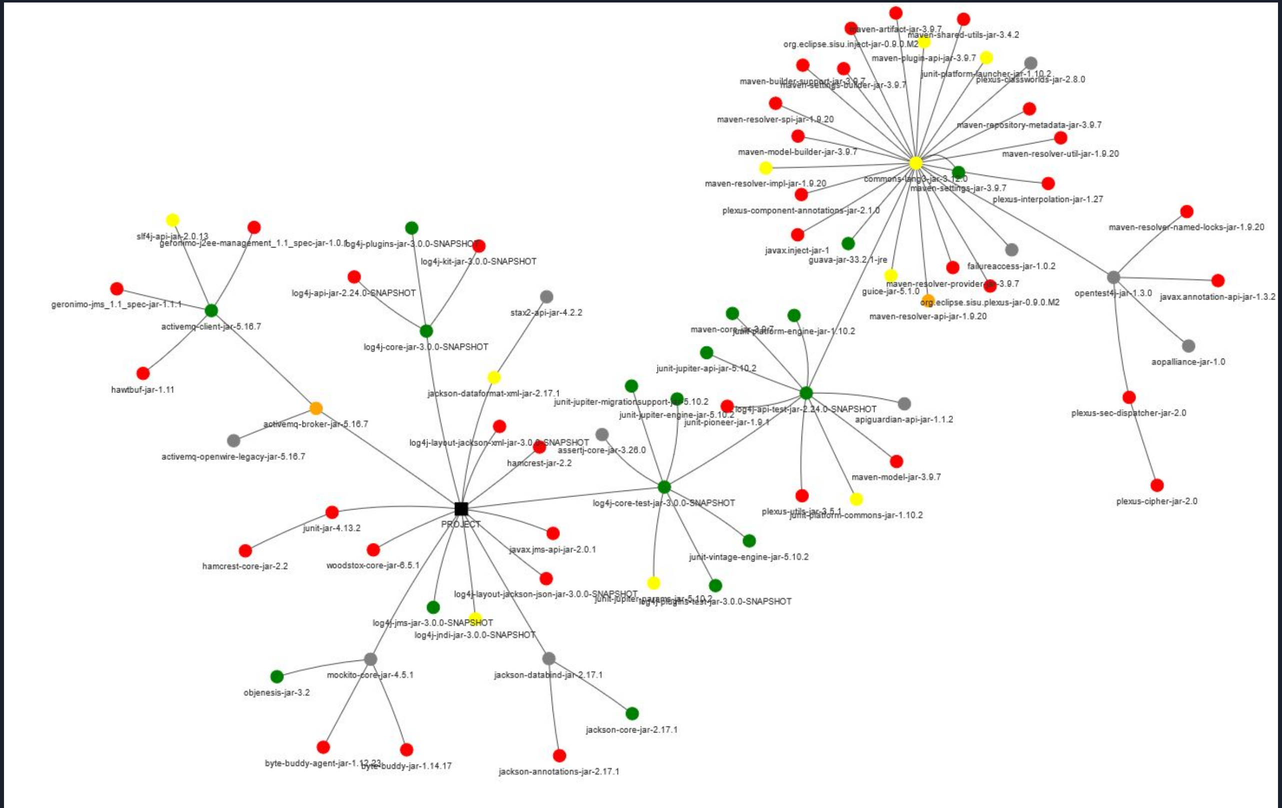
$$overallScore = (projectActivityScore + vulnerabilityScore)/2$$

- ➔ 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

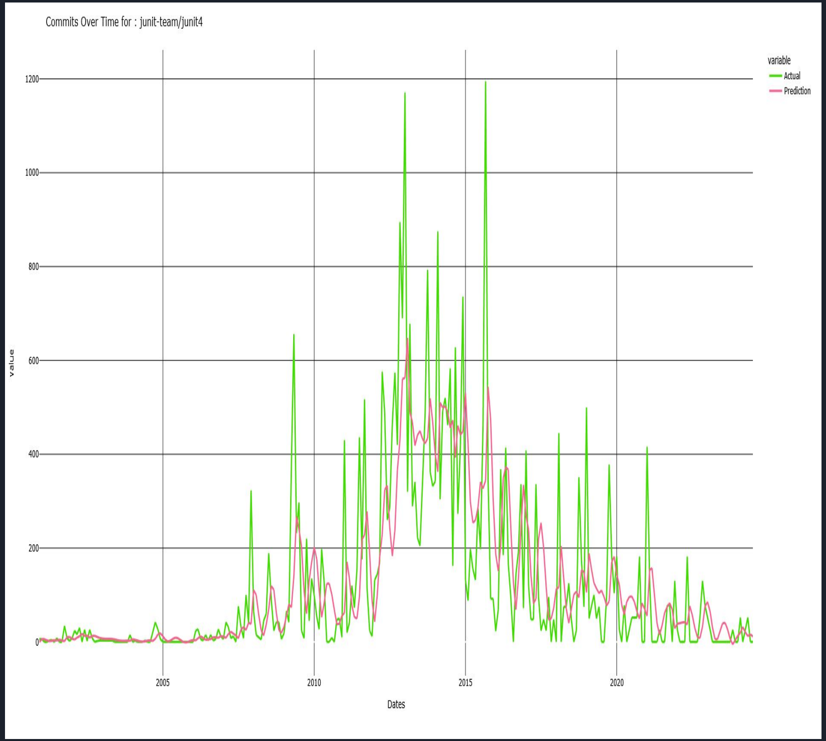
Results

Example Final Graph



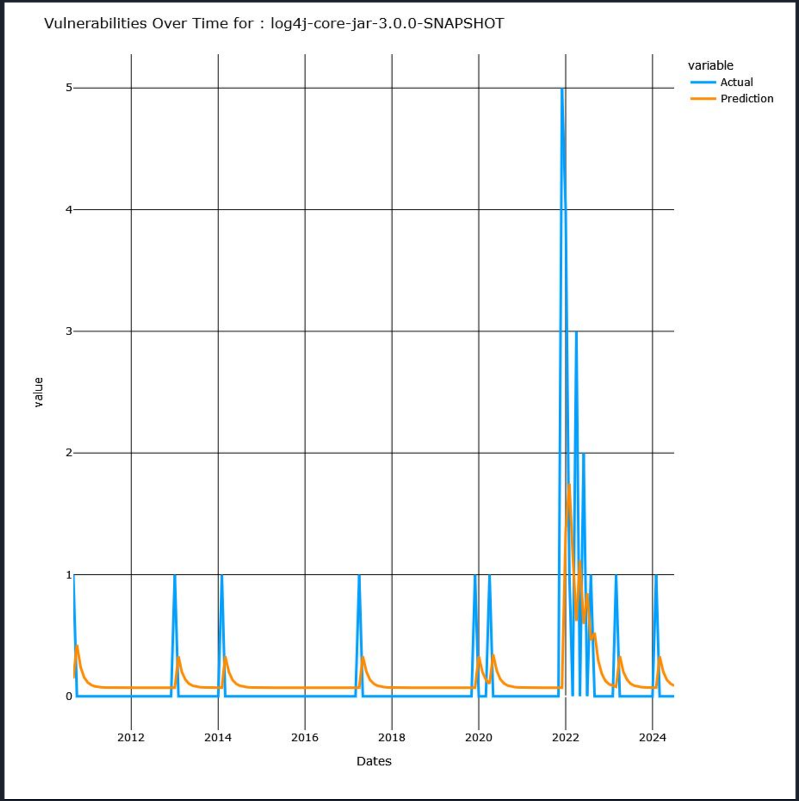
Example Graph of Project Activity Risk Prediction

- ➔ JUnit4 package commits over time
- ➔ Clear to see that activity has declined in recent years
- ➔ 2012 to 2017 were high commit years
  - ◆ At its height over 200 commits per month
- ➔ Prediction is fairly accurate as can be seen in the graph



Example Graph of Vulnerability Risk Prediction

- ➔ Log4j vulnerabilities over time
- ➔ Clear where many were released in 2021
    - ◆ 5 released in one month
- ➔ Reasonably accurate predictions in subsequent months



Evaluations

Prediction	MAPE	MAE	RMSE
Commits per month	6191.33	123.18	213.96
Vulnerabilities per month	11.51	0.15	0.48

- Log4j sample project
- Project Activity Predictions > CVE Data Predictions
- Commonly used metrics
  - Mean Absolute Percentage Error (MAPE)
  - Mean Absolute Error (MAE)
  - Root Mean Squared Error (RMSE)
- Large fluctuations in commits
- Small fluctuations in vulnerability prediction

Technical Challenges

- Graphing dependencies and dependencies of dependencies etc.
- Choosing of ARIMA parameters
  - Decided on AutoARIMA
  - PACF and ACF graphs
  - Differencing data until ADF test below 0.05
- Connecting dependencies to GitHub URLs
  - Had to be done manually

Student Contribution

Róisín Ní Bhriain

- Gitlab setup + Issues
- Literature Review
- Software
- Practicum Paper First + Second Draft

Sneha Dechamma Mallengada Suresh

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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
  - ◆ Choosing less risky modules
  - ◆ Discovering already used risky dependencies

References

Thank You For Listening!