Analyzing the effect of introducing time as a component in Python dependency graphs

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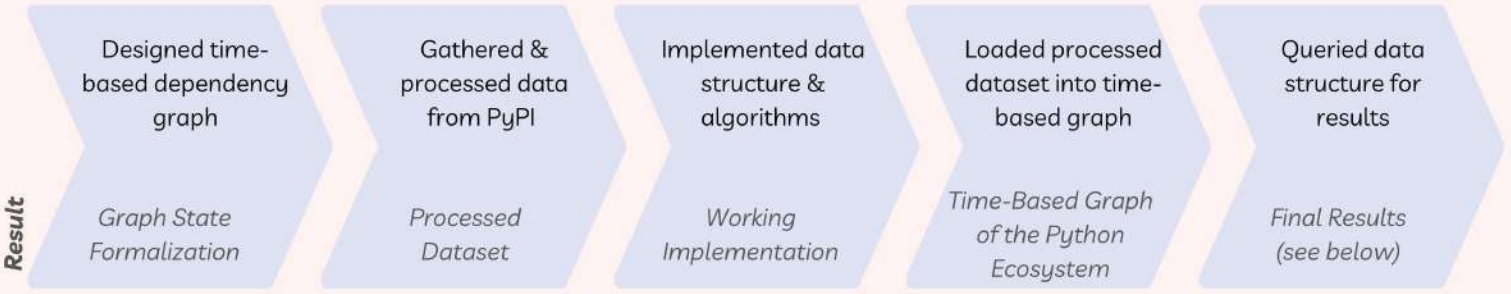
Background

- Usage of libraries improves development efficiency [1]
- **But** adding dependencies can introduce vulnerabilities
- Visualizing a project's dependencies can be achieved with dependency graphs
- **But** existing tools only target current releases
- No way to check the dependencies of a library at a given time

Objectives

- Create a **time-based dependency graph data structure**
- Analyze the **most used Python packages** at various points in time

Methodology



Designed time-based dependency graph

Gathered & processed data from PyPI

Implemented data structure & algorithms

Loaded processed dataset into time-based graph

Queried data structure for results

Result
Graph State Formalization
Processed Dataset
Working Implementation
Time-Based Graph of the Python Ecosystem
Final Results (see below)

Results

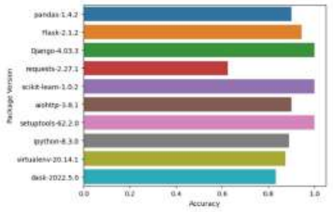
1 Formalization of the graph state

$$G_{[t_1,t_2]} = (V, E)$$

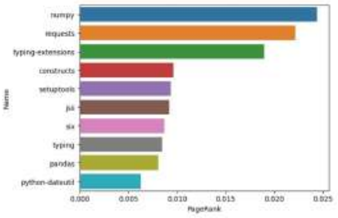
Where:

- t_1, t_2 are the timestamps that define the time frame of the state
- V is the set of all package versions, where $v \in V$ if $v_{timestamp} \in [t_1, t_2]$
- E is the set of edges, where an edge $e = (a, b)$ exists only if the package version a depends on package version b
- G is a directed graph

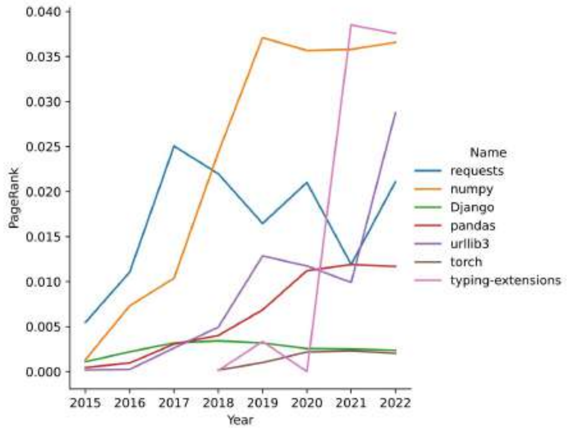
2 89.6% resolution accuracy



3 Ranking of the Top 10 most important Python packages



4 Popularity of selected packages throughout time (2015-2022)



Conclusion

- The Python ecosystem has evolved over the years, with developers using packages now more than in 2015
- There aren't any packages that once removed would collapse the entire ecosystem
- The time-based dependency graph data structure represents a step into what could be the future of dependency graph analysis

Terminology

- **Dependency** - a library that provides some functionality to other libraries
- **Dependency Graph** - a graph where each node represents a specific version of a library and the edges represent the dependency/dependent relationship
- **Transitive Dependency** - an indirect dependency resulting when the direct dependencies also have their own dependencies

Related literature

[1] Parastoo Mohagheghi and Reidar Conradi. Quality, productivity and economic benefits of software reuse: a review of industrial studies. Empirical Software Engineering, 12(5):471–516, 2007.