Open Source Software Impact Analysis Report

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1. **Background and Motivation**

The National Science Foundation (NSF) recently announced their usage of $21 million to fund open source development through a new program: Pathways to Enable Open-Source Ecosystems (PEOSE). Existing NSF-funded research projects already result in publicly accessible, modifiable, and distributable open source software, data platforms, and even open hardware that catalyzes further innovation. The NSF wants to follow the best examples of open source development where the product is widely adopted and forms the foundation of a self-sustaining open source ecosystem (OSE). A distributed community of developers and a broad base of users across academia, industry, and government make up these OSEs. Despite its extensive use, reliable measures of the scope and impact of Open Source Software (OSS) are scarce. The creation and use of OSS highlights an aspect of technology diffusion and flow that is not captured in science and technology indicators

1. **Project Summary**

Our goal was to measure the impact of OSS using network modeling and related measurements like centrality, number of package downloads, and calculating development costs leveraged through package dependencies. Network analysis approach can be applied to open source software networks to measure influence of a package similar to a node in a network using centrality measures. The dependency network is represented by a directed acyclic graph and the graph centrality measures that we used to measure influence of packages are degree, in-degree, out-degree, and eigenvector centrality. We also gathered the data and computed the number of downloads a package had, as well as the development cost for both the package itself and its dependencies. We analyzed the correlation between these statistics to determine the influential packages and find if the number of downloads, development cost, or dependency cost was related to package influence.

Additionally, we were able to associate each package with the county it was developed in based on the country of the top GitHub contributor. We used breath first search to create a package dependency tree to properly associate all of the countries a package leverages. We then aggregated cost of all of the packages on a country level to show the flow of development costs leveraged between countries. This helps to visualize the diffusion of innovation across countries, and is a framework that could be applied to organizations or other Open Source Languages as well.

1. **Data**

The data collected and analyzed in this project can be found on [ICPSR](https://www.icpsr.umich.edu/web/pages/ICPSR/index.html) with repo ids: 158827 and 16848. The data is broken down as follows:

**Google Big Query:**

* Python Packages – This is the distribution metadata table (referred to as distribution\_metadata on GCB). This table contains information about each package such as package name, version, author, maintainer, dependencies, etc. This data source is described in detail in the Appendix.
* Python Package Downloads – This is the file downloads table (referred to as file\_downloads on GCB). It contains information about each package download for the subject time period. Our analysis aims to quantify the impact of OSS software packages. Therefore, we were interested in the number of downloads completed during the subject time period not information on each individual download. Data downloaded from the file\_downloads table was aggregated by package name, version, and download country code to produce a download count. The downloads table was queried to aggregate downloads by package name, version, and country between 01/01/2020 to 01/01/2021. This data source is described in detail in the Appendix.

**Scraped GitHub Data (sponsor):**

* Commits and Sector Information – This is publicly available data on development activity of individual GitHub hosted projects and their contributors. This data was collected and aggregated by previous work conducted by Korkmaz et al. To begin, the researchers used the Ruby Gem Licensee to classify the LICENSE file in each repository. This enabled them to select only packages with OSS approved licenses. Then the GHOST.jl package was used to collect and track GitHub user attributes and scrape all the commit history. This data was filtered to exclude any forked, mirrored, or archived repositories spanning GitHub’s creation in 2008 through the end of 2019. Finally, the data was de-duplicated and filtered to exclude known bot accounts and commits merged from previous repositories. The produced commits activity data set totaled 3,260,612 distinct contributors and 7,628,101 distinct repositories. This process also gathered sector information on the GitHub contributors, which contained information such as the contributor country, organization, email, etc.

1. **Notebooks and Code**
2. [oss\_2021\_bigquery\_pypi\_meta\_downloads.ipynb](https://github.com/camillevleonard/oss_capstone_deliverables/blob/main/src/BigQuery/(1)oss_2021_bigquery_pypi_meta_downloads.ipynb) – This code is what we used to download the pypi data from Google BigQuery.
3. [master\_joins\_tables\_nb.ipynb](https://github.com/camillevleonard/oss_capstone_deliverables/blob/main/src/Notebooks/(2)master_joins_tables_nb.ipynb) – This notebook contains all of the joins and queries used to aggregate our data and create the necessary datasets.
4. [pypi\_dep\_centrality\_statistics.ipynb](https://github.com/camillevleonard/oss_capstone_deliverables/blob/main/src/Notebooks/(3)pypi_dep_centrality_statistics.ipynb) - This notebook contains our work to create and evaluate the centrality measures as well as find the correlations between our statistics.
5. [pypi\_country\_diffusion.ipynb](https://github.com/camillevleonard/oss_capstone_deliverables/blob/main/src/Notebooks/(4)pypi_country_diffusion.ipynb) – This notebook contains our diffusion cost analysis between the countries where a package was developed and the countries that are dependent upon that package.
6. **Future Work and Challenges**

Our preliminary diffusion analysis can be extended to other organizations, sectors, or other Open Source programming languages such as R. The major challenges that we ran into was missing data that prevented us from showing the full picture on our country diffusion analysis. This missing data was twofold; we lacked commit data from some of the largest packages (pandas) as they are not hosted on GitHub, which is where we sourced our commit data. We also lacked the country information on some of the largest contributors, which made it difficult to correctly attribute a package to its proper country, and as such, some packages needed to be dropped. Our current diffusion analysis accounts for only 7% of the downloaded packages between 2020 and 2021.

1. **Appendix**

## Table 1 – Distribution Metadata

The description for each field in the PyPi metadata package and additional information can be found at the following URIs:

* <https://packaging.python.org/specifications/core-metadata/>
* <https://www.python.org/dev/peps/pep-0621/>

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Field name** | **Type** | **Mode** | **Description** | **Potential Use** |
| metadata\_version | STRING | NULLABLE | Version of the file format; legal values are “1.0”, “1.1”, “1.2”, “2.1” and “2.2”.  Automated tools consuming metadata SHOULD warn if metadata\_version is greater than the highest version they support, and MUST fail if metadata\_version has a greater major version than the highest version they support (as described in PEP 440, the major version is the value before the first dot).  For broader compatibility, build tools MAY choose to produce distribution metadata using the lowest metadata version that includes all of the needed fields. |  |
| name | STRING | REQUIRED | Name of package |  |
| version | STRING | REQUIRED | Version of package |  |
| summary | STRING | NULLABLE | Short description of package |  |
| description | STRING | NULLABLE | Long description of package |  |
| description\_content\_type | STRING | NULLABLE | A string stating the markup syntax (if any) used in the distribution’s description, so that tools can intelligently render the description. |  |
| author | STRING | NULLABLE |  | Contributor network |
| author\_email | STRING | NULLABLE |  | Contributor network |
| maintainer | STRING | NULLABLE | Empty when author is current maintainer, only used when someone different than author is maintainer | Contributor network |
| maintainer\_email | STRING | NULLABLE |  | Contributor network |
| license | STRING | NULLABLE | Text indicating the license covering the distribution where the license is not a selection from the “License” Trove classifiers. See “Classifier” below. This field may also be used to specify a particular version of a license which is named via the Classifier field, or to indicate a variation or exception to such a license. | Select OSI licenses |
| keywords | STRING | NULLABLE | A list of additional keywords, separated by commas, to be used to assist searching for the distribution in a larger catalog. | Categories |
| classifiers | STRING | REPEATED | Indicates development status, can be used to find stable releases of software ([List of classifiers](https://pypi.org/classifiers/)  Development Status :: 1 - Planning  Development Status :: 2 - Pre-Alpha  Development Status :: 3 - Alpha  Development Status :: 4 - Beta  Development Status :: 5 - Production/Stable  Development Status :: 6 - Mature  Development Status :: 7 - Inactive | Categories |
| platform | STRING | REPEATED | Operating systems? |  |
| home\_page | STRING | NULLABLE | A string containing the URL for the distribution’s home page. | Getting more contributor information |
| download\_url | STRING | NULLABLE | A string containing the URL from which this version of the distribution can be downloaded. |  |
| requires\_python | STRING | NULLABLE | This field specifies the Python version(s) that the distribution is guaranteed to be compatible with. Installation tools may look at this when picking which version of a project to install. |  |
| requires | STRING | REPEATED | Dependencies uses, PEP 508 https://www.python.org/dev/peps/pep-0508/ | Dependency network |
| provides | STRING | REPEATED |  |  |
| obsoletes | STRING | REPEATED |  |  |
| requires\_dist | STRING | REPEATED | Dependencies uses, PEP 508 <https://www.python.org/dev/peps/pep-0508/>  Each entry contains a string naming some other distutils project required by this distribution.  The format of a requirement string contains from one to four parts:  A project name, in the same format as the Name: field. The only mandatory part.  A comma-separated list of ‘extra’ names. These are defined by the required project, referring to specific features which may need extra dependencies.  A version specifier. Tools parsing the format should accept optional parentheses around this, but tools generating it should not use parentheses.  An environment marker after a semicolon. This means that the requirement is only needed in the specified conditions.  See PEP 508 for full details of the allowed format.  The project names should correspond to names as found on the Python Package Index.  Version specifiers must follow the rules described in Version specifiers. |  |
| provides\_dist | STRING | REPEATED | Changed in version 2.1: The field format specification was relaxed to accept the syntax used by popular publishing tools.  Each entry contains a string naming a Distutils project which is contained within this distribution. This field must include the project identified in the Name field, followed by the version : Name (Version).  A distribution may provide additional names, e.g. to indicate that multiple projects have been bundled together. For instance, source distributions of the ZODB project have historically included the transaction project, which is now available as a separate distribution. Installing such a source distribution satisfies requirements for both ZODB and transaction.  A distribution may also provide a “virtual” project name, which does not correspond to any separately-distributed project: such a name might be used to indicate an abstract capability which could be supplied by one of multiple projects. E.g., multiple projects might supply RDBMS bindings for use by a given ORM: each project might declare that it provides ORM-bindings, allowing other projects to depend only on having at most one of them installed.  A version declaration may be supplied and must follow the rules described in Version specifiers. The distribution’s version number will be implied if none is specified.  This field may be followed by an environment marker after a semicolon. |  |
| obsoletes\_dist | STRING | REPEATED | Changed in version 2.1: The field format specification was relaxed to accept the syntax used by popular publishing tools.  Each entry contains a string describing a distutils project’s distribution which this distribution renders obsolete, meaning that the two projects should not be installed at the same time.  Version declarations can be supplied. Version numbers must be in the format specified in Version specifiers.  This field may be followed by an environment marker after a semicolon.  The most common use of this field will be in case a project name changes, e.g. Gorgon 2.3 gets subsumed into Torqued Python 1.0. When you install Torqued Python, the Gorgon distribution should be removed. |  |
| requires\_external | STRING | REPEATED | Changed in version 2.1: The field format specification was relaxed to accept the syntax used by popular publishing tools.  Each entry contains a string describing some dependency in the system that the distribution is to be used. This field is intended to serve as a hint to downstream project maintainers, and has no semantics which are meaningful to the distutils distribution.  The format of a requirement string is a name of an external dependency, optionally followed by a version declaration within parentheses.  This field may be followed by an environment marker after a semicolon.  Because they refer to non-Python software releases, version numbers for this field are not required to conform to the format specified in PEP 440: they should correspond to the version scheme used by the external dependency.  Notice that there is no particular rule on the strings to be used. |  |
| project\_urls | STRING | REPEATED | Links to various things like documentation, repo, probably not useful to us |  |
| uploaded\_via | STRING | NULLABLE |  |  |
| upload\_time | TIMESTAMP | NULLABLE |  |  |
| filename | STRING | NULLABLE |  |  |
| size | INTEGER | NULLABLE |  |  |
| path | STRING | NULLABLE |  |  |
| python\_version | STRING | NULLABLE | Python version, can be used to filter data within scope, format of this column varies (cp27, cp36, source, etc) | Filtering data |
| packagetype | STRING | NULLABLE | Options [bdist\_egg, bdist\_dumb, bdist\_wininst, bdist\_msi, sdist, bdist\_wheel, bdist\_rpm, bdist\_dmg] |  |
| comment\_text | STRING | NULLABLE | Mostly null |  |
| has\_signature | BOOLEAN | NULLABLE | Don’t know what this represents |  |
| md5\_digest | STRING | REQUIRED | Hash |  |
| sha256\_digest | STRING | NULLABLE | Hash |  |
| blake2\_256\_digest | STRING | NULLABLE | Hash |  |

Caveats

In addition to the caveats listed in the background above, Linehaul suffered from a bug which caused it to significantly under-report download statistics prior to July 26, 2018. Downloads before this date are proportionally accurate (e.g. the percentage of Python 2 vs. Python 3 downloads) but total numbers are lower than actual by an order of magnitude. [[Source](https://packaging.python.org/guides/analyzing-pypi-package-downloads/)]

## Table 2 - File Downloads

Name indented according to nesting. I believe this data is in JSON format.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **name** | **Type** | **Mode** | **Description** | **Potential Use** |
| timestamp | TIMESTAMP | REQUIRED |  |  |
| country\_code | STRING | NULLABLE |  |  |
| url | STRING | REQUIRED |  |  |
| project | STRING | REQUIRED | Project name |  |
| file | RECORD | REQUIRED |  |  |
| filename | STRING | NULLABLE |  |  |
| project | STRING | NULLABLE |  |  |
| version | STRING | NULLABLE |  |  |
| type | STRING | NULLABLE |  |  |
| details | RECORD | NULLABLE |  |  |
| installer | RECORD | NULLABLE |  |  |
| name | STRING | NULLABLE | Name of installer |  |
| version | STRING | NULLABLE |  |  |
| python | STRING | NULLABLE |  |  |
| implementation | RECORD | NULLABLE |  |  |
| name | STRING | NULLABLE |  |  |
| version | STRING | NULLABLE |  |  |
| distro | RECORD | NULLABLE |  |  |
| name | STRING | NULLABLE |  |  |
| version | STRING | NULLABLE |  |  |
| id | STRING | NULLABLE |  |  |
| libc | RECORD | NULLABLE |  |  |
| lib | STRING | NULLABLE |  |  |
| version | STRING | NULLABLE |  |  |
| system | RECORD | NULLABLE |  |  |
| name | STRING | NULLABLE |  |  |
| release | STRING | NULLABLE |  |  |
| cpu | STRING | NULLABLE |  |  |
| openssl\_version | STRING | NULLABLE |  |  |
| setuptools\_version | STRING | NULLABLE |  |  |
| tls\_protocol | STRING | NULLABLE |  |  |
| tls\_cipher | STRING | NULLAB |  |  |