maintaineR: A web-based dashboard for maintainers of CRAN packages

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Abstract—The $R$ development community maintains thousands of packages through its Comprehensive $R$ Archive Network CRAN. The growth and evolution of this archive makes it more and more difficult to maintain packages and their interdependencies, and the existing tools that aim to help developers in this process no longer suffice. We propose maintaineR, a web-based dashboard that allows CRAN package developers to understand and deal with the implications and problems raised by package updates. The dashboard complements existing analysis tools by providing additional support such as the visualisation of package dependencies and reverse dependencies, package conflicts, cross-package function clones, and so on.

I. INTRODUCTION

Many generic web-based dashboards exist to help developer communities with specific maintenance activities. For dedicated software developer communities involved a specific software ecosystem (including specific programming languages, development processes tools, guidelines, rules and hardware infrastructure), targeted web-based dashboards are however not always available, or need to be improved to accommodate the specific needs of developers.

The maintaineR dashboard focuses on the $R$ project community (www.r-project.org). $R$ offers a free and open source language and environment for statistical computing and visualisation. Its community is composed of thousands of developers, involved in maintaining thousands of packages. The CRAN package repository (cran.r-project.org), available since 1997, is the primary source of $R$ packages. Other available $R$ package repositories (e.g., Bioconductor and R-forge) are considerably smaller in size.

The number of available CRAN packages is growing very rapidly and has reached a size of over 5000 packages, which is considered by some as “too many” [1]. In addition, limitations of $R$’s dependency versioning system have been reported and possible directions for improvement (such as staged package distributions and versioned package management) have been proposed [2]. Another problem is a lack of coordination between maintainers of dependent packages. Packages may cease to function correctly because of unexpected changes made to the packages they rely upon.

Therefore, there is a need for more specific tools dedicated to $R$ package developers, that allow them to gain insight in, and deal with, the implications and problems raised by package updates. Being able to address such problems a priori during package development and maintenance, i.e., long before submitting it to CRAN, will reduce the effort of maintaining contributed CRAN packages.

We developed maintaineR, a web-based dashboard to alleviate the above problems. It can be downloaded on github.com/maellick/maintaineR, together with clear installation instructions. A screencast is available on youtu.be/q3RWTsVnPqg. maintaineR is more specific and fine-grained than what is currently available to CRAN maintainers. It helps them to identify and avoid problems that could break their own package or those of others. The tool is based on a fine-grained function-level analysis of dependencies, conflicts and clones (copy-paste reuse of code) between packages.

II. RELATED WORK AND EXISTING TOOLS

maintaineR aims to help in understanding and supporting the maintenance of software ecosystems and their components. We adhere to the definition by Messerschmitt [3] who defines a software ecosystem as “a collection of software products that have some given degree of symbiotic relationships.” Stated differently, a software ecosystem constitutes an evolving collection of software projects/components/packages that share a common goal, as well as human and technical resources.

Several tools have been proposed to analyse, understand and visualise software ecosystems and their evolution. For example, Neu et al. [4] developed Complicity, a web-based application aiming to support software ecosystem analysis through interactive visualisations. Perez et al. [5] presented SECONDA, a software ecosystem analysis dashboard. The goal of maintaineR is similar in spirit, namely to provide a web-based dashboard for analysing and understanding the CRAN ecosystem and the packages it contains.

Another type of software ecosystems are the so-called software distributions, which are collections of software components that are bundled together in such a way that they can be installed and used “as is” by an end-user for its intended purpose. From a maintenance point of view, this raises additional problems, since the maintainers of the software components need to avoid broken dependencies or other conflicts whenever they upgrade a component. Di Cosmo et al. have formally studied this problem of coinstallability and provided tool support for addressing it [6], [7]. CRAN may benefit from similar support. In particular, more fine-grained analysis of CRAN package dependencies and how these affect maintenance and update of packages is needed. Although some empirical studies of CRAN have been carried out [8], [9].

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we are not aware of any web-based applications aiming to provide sophisticated support for understanding and improving the maintenance of CRAN contributed packages.

Of course, many generic web-based tools are available that provide insight in the evolution of software products by analysing historical data extracted from version control repositories using a combination of metrics, visualisation and statistics. Well-known examples of these are SonarQube™ (www.sonarqube.org) that provides an extensible open source platform for managing code quality, and GitHub that includes a variety of views on the version control activity of ongoing projects, including network visualisations and historical visualisations. The main difference is that maintaineR offers dedicated support for CRAN, taking into account the specificities of the R language and the processes and tools used by CRAN package maintainers.

III. ABOUT CRAN CHECK

CRAN follows a strict policy\(^1\) that packages need to adhere to before being accepted on the repository\(^2\). CRAN package developers can use the R CMD check command at any time to detect possible problems in their contributed packages. This tool is also used to ensure conformance of accepted packages to the CRAN quality policy, and a daily check on the full set of packages is applied to detect which packages no longer pass the test. After certain package updates, other dependent packages may cease to work correctly if the functions they were relying on have changed. Packages can also fail the check if a new R release introduces, changes or removes features.

While packages are never removed from CRAN, they can eventually be archived. Maintainers have to ensure that their packages still pass the test with latest R and CRAN package versions. If this is not the case, maintainers have to fix the problems before the next non-minor R release or to stick to a strict deadline short after this release. If they don’t, their buggy packages will be archived. A major issue with CRAN is that it is only guaranteed to work properly with the last version of R and vice versa. Given that only basic tools exist to manage different versions of a package in the same R installation, it is very difficult to work with them in practice.

While the R CMD check results are useful for CRAN maintainers to detect problems with their package, it does not give sufficient information about the origin of the failure when it is caused by changes in code of dependencies. Therefore, R maintainers could benefit from a more specific tool using knowledge about all previous packages versions in order to identify causes of current errors and avoid future possible errors. This is what maintaineR aims to provide.

IV. TOOL PRESENTATION

This section presents maintaineR, a web-based dashboard for supporting CRAN package maintainers. This tool helps with analysing and visualising the implications and problems raised by package updates. Its functionalities are likely to evolve in the future, based on feedback that we will receive from researchers and the R community.

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\(^1\) cran.r-project.org/web/packages/policies.html
\(^2\) cran.r-project.org/web/checks/
**Summary** shows a table containing the context of the package’s `DESCRIPTION` file.  
**History** shows the release history of the package, its dependencies and/or its reverse dependencies.  
**Dependency list** shows the list of all dependencies and reverse dependencies of a package.  
**Dependency graph** visualises dependencies either as a graph or a Sankey diagram.  
**Namespace** shows all public objects declared in the package namespace and the potential conflicts with objects using the same name in other packages.  
**Clones** displays all function clones that are present in all other CRAN packages.

### B. Historical view

An example of the historical view is given in Fig. 2. By default, it shows the release dates of the package on a timeline. As shown in Fig. 2 it is possible to restrain the timeline to a shorter period and to add dependencies to and reverse dependencies from other packages. The ability to visualise globally the history of release dependencies is useful for a developer in order to spot recent changes when the package encounters an error during a CRAN web check.

### C. Package dependency analysis

It is well-known that the presence of dependencies may cause problems during the evolution of component-based systems [6], [7]. We have empirically studied this problem for CRAN [9] and observed that package quality and maintainability varies with the operating system considered. We also observed that a non-negligible amount of errors are caused by dependency updates and need to be fixed by the maintainers. Maintenance effort hence needs to take into account changes made to package dependencies.

The CRAN policy recommends not to break reverse dependencies (i.e., packages that depend directly on it). However, this is only a recommendation and not a rule. Furthermore, while the CRAN website lists for each package all reverse dependencies, there is no tool to check that changes made to a package won’t impact these other packages.

It is therefore important to offer package maintainers an easy way to visualise the direct and indirect dependencies and reserve dependencies of their packages. Fig. 3 shows such a visualisation generated by our tool for a given CRAN package.

### D. Detection of package function conflicts

R resolves function and variable names using environment objects, which are hash tables associating names to objects exported by the package namespace. When a variable or a function is referenced, the interpreter cycles through a list of environments. When two packages define the same function name, the last imported function will mask the first imported one. Although it is still possible to call the first function by specifying the package name with a special notation, this can lead to conflicts. For example, suppose that package A depends on packages B and C and uses a function `f` defined in B. If a new version of package C introduces a new function with the same name `f`, there is a chance that this creates a conflict.

Fig. 4 shows the Namespace view for a given CRAN package, displaying the function and variable names exported by the package namespace, and the potential conflicts this introduced with (particular versions of) other packages. To achieve this, we used Vagrant and VirtualBox to create a virtual machine running on Debian for each version of R. On all these virtual machines we installed all available CRAN packages at the time of the release of the machine’s R version. We loaded...
Fig. 5. **Clones** view for the CRAN package DescTools (version 0.99.6), filtered to show only clones of at least 3 lines and an AST of size at least 10.

Fig. 4. **Namespace** view for the CRAN package abc (version 1.8).

all these packages one by one and we exported the list of objects available in the package environment.

**E. Detection of function clones**

As depending on another package can be costly from a maintenance perspective, it is common for CRAN package maintainers to copy-paste portions of code from other packages rather than depending upon them. Developers also frequently write local functions inside the body of other functions (like a closure). Often, these functions do not reference any local variable and could therefore easily have been defined in the global scope of the package. Not doing so prevents dependent packages to reuse these functions.

The Clones view of our tool, displayed in Fig. 5, determines which global or local functions defined in the package are perfect duplicates (so-called “Type 1” clones) of a function defined in another package. The user interface allows to display only clones that corresponds to the last available version of CRAN packages. Clones are detected by parsing the R code of all packages, performing a depth-first traversal of the abstract syntax tree, computing a hash for each node, and adding all function definitions in a hash table using the computed hash key. All keys associated with more than one package correspond to cloned functions.

**V. CONCLUSION AND FUTURE WORK**

We presented maintaineR, a web-based dashboard for analysing maintainability of CRAN packages, by offering analyses and visualisation of the package release history, package dependencies, potentially conflicting function names across packages, and identical function clones. We will actively promote take-up of our dashboard by the CRAN developer community, and we intend to improve the tool based on feedback received from CRAN package maintainers. We intend to use the tool ourselves for carrying out empirical analyses of the CRAN ecosystem. Our tool can be extended in many ways. We will improve the current functionalities with new visualisations and more sophisticated analyses. For example, we will detect if the conflicting functions are clones. We also intend to create a function call graph in order to show a finer-grained view of package maintenance problems. We also intend to provide a view allowing maintainers to test the new version of their package before sending it to CRAN in order to detect conflicts and problems introduced in the package or in the packages relying on it. Next to the current package-oriented view, we aim to provide a maintainer-oriented view, as well as a global ecosystemic view of CRAN’s socio-technical ecosystem. Through our virtual-machine-based approach, we also aim to provide support for reproducibility of research studies that relied on older CRAN package versions.

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**REFERENCES**