Prospects and Challenges for CRAN – with a glance on Ubuntu binaries

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The R Project for Statistical Computing

useR! 2010, Gaithersburg
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Cornerstones of R’s success:

- Decentralized and modularized way of creating software
- Standardized format of packages and package system
- Accessibility by a broad audience: standardized repositories
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CRAN repository contains more than 2460 packages

- Ease of installing packages
- Checks help to provide at least some kind of quality
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CRAN repository contains more than 2460 packages
- Ease of installing packages
- Checks help to provide at least some kind of quality

To support such a loosely coupled development model:
- verification of certain formal quality criteria
Established quality assurance systems and collaborative infrastructures typically face several challenges.

More and more has been or has to be automated: R package management system has gone a long and successful way to also support repository maintainers, but we have to go further.

Services:
- Check result summaries
- Binaries
- Other support of the loosely coupled development model
Products

We can think of

- packages as ‘products’,
- potential users as ‘customers’,
- package repositories like CRAN: ‘warehouse’-like storage areas.
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- packages as ‘products’,
- potential users as ‘customers’,
- package repositories like CRAN: ‘warehouse’-like storage areas.

If the ‘right’ product is not available:

- Easy for customers to become contributors: creating new package to fill the gap
- Decentralized and modularized way of creating software
- Rather then reinventing the wheel, package authors wisely reuse code of other packages
Repositories

- CRAN, BioConductor, Omega(hat), R-Forge, and many others
- Publication mechanism for CRAN:
  - Submit contributed source package via ftp upload
  - Notify CRAN maintainers
  - Package checked by a CRAN maintainer
  - If fine, package is included for provision.
  - Binary versions are created and checked
  - Regular checks
Other OSS Repositories

Other Open Source Software Repositories:

- Debian GNU Linux
- Other Linux distributions
- Perl (CPAN)
- ...

Debian GNU Linux offers a very sophisticated package management system and pursues an approach similar to CRAN:

- Relationships between packages declared in the package’s control file
  (Depends, Recommends, Suggests, Enhances, etc.)
- Packages are checked for certain formal quality criteria
Dependencies

- Packages might depend on other packages that again depend on ...
- Hierarchy of dependencies could be broken by a simple bug in one of the packages: implications on the interoperability between packages
- Check system that allows for recursive checking
- Check system for huge package repositories should be parallelized: deal with thousands of packages while respecting dependency structures
Dependency levels

Package maintainers specify dependencies in the DESCRIPTION file:

**Depends:** Package B depends on functionality in package A in such a way that package A is loaded in advance of B

**Imports:** Package B imports (parts of) the namespace of package A into its own namespace

**LinkingTo:** Package B links to compiled code in package A

**Suggests:** Some functionality or examples in the documentation of package B depend on package A

**Enhances:** Package B enhances packages A functionality but works without A being present
**Dependency levels**

- *Depends, Imports* and *LinkingTo* must be fulfilled at installation time.
- *Suggests* must typically be available when a package is checked.
- Usually two different types of dependency graphs have to be calculated:
  - Graphs needed for finding the correct installation order.
  - Graphs needed for finding what have to be checked.
(Reverse) dependencies

Consider

- package $B$ depends on package $A$; formally denoted $A \in d(B)$, where $d(B)$ entails all dependencies of $B$
- packages $C$ and $D$ depend on package $B$, i.e. $A \in d_R(C)$, $A \in d_R(D)$
- $d_R(D)$ denotes all recursive dependencies of package $D$, i.e. the transitive closure of all dependencies of $D$. Then once $A$ is updated, we definitely need to
  - re-check packages $A$, $B$, $C$, and $D$, because newly introduced features or changes in $A$ could have broken something somewhere else.
Reverse dependencies of $A$ denoted $d^{-1}(A)$, i.e., all packages depending on $A$.

Recursive reverse dependencies: $C \in d^{-1}_{R}(A)$ has to be considered for re-checking interoperability.

With growth of CRAN: frequently an update of one package $P$ breaks code in some dependent package(s) $d^{-1}_{R}(P)$.
**Reverse dependencies**

- Reverse dependencies of $A$ denoted $d^{-1}(A)$, i.e., all packages depending on $A$.
- Recursive reverse dependencies: $C \in d^{-1}_{R}(A)$ has to be considered for re-checking interoperability.
- With growth of CRAN: frequently an update of one package $P$ breaks code in some dependent package(s) $d^{-1}_{R}(P)$.
- Wonder why CRAN worked fairly well until 2008 without these checks
(Reverse) dependencies

- We even may need – in addition to a new binary for A – some updated binary packages for B, C and D: e.g. if S4 classes and/or saved images are involved
- Find out which other packages are ‘involved’ (inclusive the recursive dependencies) in an update of a given package using

```r
tools::dependsOnPkgs(pkgs,
  dependencies = c("Depends", "Imports", "LinkingTo"),
  recursive = TRUE, lib.loc = NULL,
  installed = installed.packages(lib.loc,
    fields = "Enhances"))
```
(Reverse) dependencies

Number of CRAN packages with 0, 1, . . . , and max. number of (recursive / reverse) dependencies:

<table>
<thead>
<tr>
<th>dependencies</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>flat</td>
<td>809</td>
<td>573</td>
<td>365</td>
<td>227</td>
<td>180</td>
<td>97</td>
<td>57</td>
<td>19</td>
</tr>
<tr>
<td>recursive</td>
<td>809</td>
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<td>182</td>
<td>126</td>
<td>93</td>
<td>120</td>
<td>110</td>
<td>33</td>
</tr>
<tr>
<td>flat reverse</td>
<td>1614</td>
<td>336</td>
<td>132</td>
<td>83</td>
<td>33</td>
<td>37</td>
<td>20</td>
<td>313</td>
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<tr>
<td>recursive reverse</td>
<td>1614</td>
<td>245</td>
<td>106</td>
<td>66</td>
<td>52</td>
<td>25</td>
<td>20</td>
<td>1141</td>
</tr>
</tbody>
</table>

based on dependency levels

- *Depends, Imports, LinkingTo*
- plus *Suggests* for flat reverse and recursive reverse dependencies
(Reverse) dependencies

Selected CRAN packages with extreme number of (recursive / reverse) dependencies

<table>
<thead>
<tr>
<th>dependencies</th>
<th>MASS</th>
<th>survival</th>
<th>Metabonomics</th>
<th>sisus</th>
</tr>
</thead>
<tbody>
<tr>
<td>flat</td>
<td>4</td>
<td>4</td>
<td>19</td>
<td>18</td>
</tr>
<tr>
<td>recursive</td>
<td>4</td>
<td>4</td>
<td>33</td>
<td>31</td>
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<tr>
<td>flat reverse</td>
<td>313</td>
<td>127</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>recursive reverse</td>
<td>1065</td>
<td>1141</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

based on dependency levels

- *Depends, Imports, LinkingTo*
- plus *Suggests* for flat reverse and recursive reverse dependencies
(Reverse) dependencies

- CRAN’s dependency matrix is sparse
- Roughly half (> 1000) of all CRAN packages ‘depend’ (recursively) on packages MASS or survival
- This is a problem given the runtime and many package updates a day — at least without allowing for parallel checks (and installs)
(Reverse) dependencies

- CRAN’s dependency matrix is sparse
- Roughly half (> 1000) of all CRAN packages ‘depend’ (recursively) on packages MASS or survival
- This is a problem given the runtime and many package updates a day — at least without allowing for parallel checks (and installs)
- Let us take look at dependency graphs created with the help of package *igraph*
Dependency graph for package TIMP
dependency levels: Depends, Imports and LinkingTo
Graph representing the recursive reverse dependencies of package `Matrix` as needed in every new check of the given package; dep. levels: `Depends`, `Imports`, `LinkingTo`, and `Suggests`
(Reverse) dependencies

Graph representing the recursive reverse dependencies of package Matrix as needed in every new check of the given package; dep. levels: Depends, Imports, LinkingTo, and Suggests

(558 packages)
Graph representing the recursive reverse dependencies of package *clue* as needed in every new check of the given package; dep. levels: *Depends, Imports, LinkingTo*, and *Suggests*
Resources

- Combinations of different flavors of R:
  - branches: *devel*, *patched*, and *release*
  - platforms: Linux, Mac OS X, Solaris, Windows
  - architectures: SPARC, i86, x86_64

- Building and checking of packages on all combinations can become rather time consuming, particularly for checking reverse recursive dependencies

- Development version of R changes over time:
  - regular checks (up to daily)
Computer resources

- Desirable to get check results for development processes early
- Build/check system required that
  - finished within (at least!) 24 hours
  - for each flavor of R in order to
  - provide the check results when needed, not thereafter
  - make binaries available in time during an R release cycle (e.g. the day after alpha/beta/rc/release)
- [http://CRAN.R-project.org/web/checks/check_timings.html](http://CRAN.R-project.org/web/checks/check_timings.html)
Why should we ‘improve’ computer resources?

Tasks of a CRAN auto-build-and-check machine

- Make R-devel (3 times a week?)
- Build and check new and updated packages at least for R-release, R-devel, and R-oldrelease (?):
  - including reverse dependencies
  - each 6 hours
- Notifications for developers (at least in case of ERRORS?)
- Check summaries
Computer resources

Why should we ‘improve’ computer resources?

Tasks of a CRAN auto-build-and-check machine

- Re-check all packages for R-devel (and R-patched?) on a regular (weekly?) basis

**Aim:** make it possible to look out for errors for both R Core developers and package developers

- Provide the ftp check system for package developers as a service
CRAN Windows Binaries’ Package Check


<table>
<thead>
<tr>
<th>No</th>
<th>Package</th>
<th>Version</th>
<th>R-2.3.1</th>
<th>Inst. time</th>
<th>Check time</th>
</tr>
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<tbody>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>742</td>
<td>wavelets</td>
<td>0.2-1</td>
<td>OK</td>
<td>26</td>
<td>88</td>
</tr>
<tr>
<td>743</td>
<td>waveslim</td>
<td>1.5</td>
<td>OK</td>
<td>58</td>
<td>109</td>
</tr>
<tr>
<td>744</td>
<td>wavethresh</td>
<td>2.2-8</td>
<td>OK</td>
<td>30</td>
<td>75</td>
</tr>
<tr>
<td>745</td>
<td>wccsom</td>
<td>1.1.0</td>
<td>OK</td>
<td>18</td>
<td>87</td>
</tr>
<tr>
<td>746</td>
<td>wle</td>
<td>0.9-2</td>
<td>OK</td>
<td>24</td>
<td>365</td>
</tr>
<tr>
<td>747</td>
<td>xgobi</td>
<td>1.2-13</td>
<td>ReadMe</td>
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<td></td>
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<td>xtable</td>
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<td>OK</td>
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<tr>
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<td>WARNING</td>
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<td>46</td>
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<tr>
<td>750</td>
<td>zoo</td>
<td>1.1-0</td>
<td>OK</td>
<td>23</td>
<td>60</td>
</tr>
</tbody>
</table>

SUM (in hours) on **Xeon 3.06 GHz**: 6.34 19.77 \(\approx 26\) hours
CRAN Windows Binaries’ Package Check
2010

Last updated on 2010-07-16 19:50:06 (**last Friday**)  (**simplified**)

<table>
<thead>
<tr>
<th>No</th>
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<th>Version</th>
<th>R-2.11.1</th>
<th>Inst. time</th>
<th>Check time</th>
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<tbody>
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<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
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<td>zic</td>
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<td>OK</td>
<td>36</td>
<td>17</td>
</tr>
<tr>
<td>2459</td>
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<td>0.6-5</td>
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<td>7</td>
<td>63</td>
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<tr>
<td>2460</td>
<td>zoeppritz</td>
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<td>OK</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>2461</td>
<td>zoo</td>
<td>1.6-4</td>
<td>OK</td>
<td>4</td>
<td>62</td>
</tr>
<tr>
<td>2462</td>
<td>zyp</td>
<td>0.9-1</td>
<td>OK</td>
<td>1</td>
<td>18</td>
</tr>
</tbody>
</table>

Sum (in hours), **2x Xeon E5430 Quad**: 6.9/8 50.6/8
≈ **8 hours**
Due to the requirements for the CRAN maintenance, parallel package installation has been made possible since R-2.9.0

- Per package locks rather than per library locks (00LOCK)
- Package dependencies are calculated in R
- Written to a Makefile
- Finally resolved by `make -jX`
Parallel installations

Makefile (as used on CRAN):

```makefile
PKG := packageA packageB packageC
PKG_INST := $(PKG:=-install.out)
all: $(PKG_INST)
%-install.out: %
        MAKE=make MAKEFLAGS= R -f install.R\
               --vanilla --quiet --args Path/to/library\n               build $< R_default_packages=NULL
packageA-install.out: packageB-install.out
...  
[one line for each package]
```
Parallel installations

Parallel installations on user level

- within R

  ```
  install.packages(pkgs, lib, ......,
  Ncpus =getOption("Ncpus"), ...) 
  ```

- which generates the Makefile and several instances of R CMD INSTALL --pkglock ..... are used (which is also possible on user level).
Human resources

It is all automated, so what?

Tasks of a repository maintainer

- Maintaining and adapting the scripts themselves
- Maintaining the hardware of a devoted machine
- Setting up repositories for new versions of R
- Handling errors that were not covered by the scripts
- Answering questions (for developers and users)
- Asking package maintainers to fix their packages

Quality management can be improved by moving as many tasks as possible from human to computational resources.
Base system vs. packages

- Functionality of the base R system is defined, well tested, and the code base of the current “stable” branch does not change significantly
- New version of R is released twice a year
- Only bugfixes are provided between releases (‘patched’ flavor of R)
- For packages, contributors upload code without a specific schedule
- Release vs. (current) development platforms
Solutions: R-Forge

R-Forge (http://R-Forge.R-project.org), for the distributed development approach of packages, offers:

- Central platform for the development of R packages and other projects
- Organized in ‘project’
- Various tools and web-based features for software development, communication and other services
- SVN repository
- CRAN-style repository of R packages built from the committed source code
- Reflecting the development progress made in the repository
Solutions: R-Forge

- Social networking?
Solutions: R-Forge

- Social networking?
- Allow developer to check if some package update will break code in other packages before the CRAN release (expensive!)
Solutions: Build and check systems

Package developers without access to Windows machines for building or testing purposes may use

- special service called *win-builder*
- http://win-builder.R-project.org
- Allows to upload source packages and provides corresponding Windows binaries and check results
- Such services may appear for more than just the Windows platform on R-Forge ‘soon’
... glance on 64-bit Windows binaries

- 64-bit Windows binaries are available since early 2010
- Shortly after a suitable compiler collection (gcc-4.4.x, MinGW beta) was released
- Notification by Arm Gong on January 04, 2010
- First official release with R-2.11.0
- Allows for processes using $> 2$Gb
- Binaries distributed separately:
  separate installer, separate checks, separate binary repositories:
  - CRAN-mirror/bin/windows/contrib/2.11
  - CRAN-mirror/bin/windows64/contrib/2.11
- Speed: Seems to be faster than 32-bit – but with a different more recent compiler version
CRAN checks (July 20, 2010)

http://cran.r-project.org/web/checks/check_summary.html:

<table>
<thead>
<tr>
<th>Flavor</th>
<th>OK</th>
<th>WARN</th>
<th>ERROR</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>r-devel-linux-ix86</td>
<td>2195</td>
<td>248</td>
<td>17</td>
<td>2460</td>
</tr>
<tr>
<td>r-devel-linux-x86_64-gcc-debian</td>
<td>2188</td>
<td>244</td>
<td>28</td>
<td>2460</td>
</tr>
<tr>
<td>r-devel-linux-x86_64-gcc-fedora</td>
<td>2197</td>
<td>244</td>
<td>20</td>
<td>2461</td>
</tr>
<tr>
<td>r-patched-linux-ix86</td>
<td>2229</td>
<td>220</td>
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<td>2460</td>
</tr>
<tr>
<td>r-patched-linux-x86_64</td>
<td>2218</td>
<td>219</td>
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<td>2460</td>
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<tr>
<td>r-patched-solaris-sparc</td>
<td>2128</td>
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<tr>
<td>r-patched-solaris-x86</td>
<td>2128</td>
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<td>r-release-linux-ix86</td>
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<td>2217</td>
<td>168</td>
<td>40</td>
<td>2425</td>
</tr>
</tbody>
</table>
We aim at having bi-arch binaries for R-2.12.x (release to be in October?)

- Both 32-bit and 64-bit binary parts in one package
- Many parts of base R and binary packages are independent of 32-bit vs. 64-bit
- Just one repository required
- Install and check time reduced: Only parts depending on ‘bit’ have to be done twice
- Shared libraries (DLLs) in `./libs/i386/`, `./libs/x64/`
- Same true for directories `./bin/` and `./etc/` in base R
64-bit Windows binaries for R-2.12.x

- MinGW-w64 ‘1.0’ changed to gcc pre-4.5.1
  (underscore conventions changed)
- Package authors using ‘configure.win’ or ‘Makefile.win’
  are encouraged to switch to ‘Makevars.win’, if applicable
Prospects and Challenges

Prospects of a loosely-coupled development approach are diverse:

- Rapid development
- Diversity
- Alternative approaches facing different aspects of implementations such as speed vs. accuracy

Challenges are diverse, many solutions that have been implemented / are shortly before being implemented:

- (Recursive / reverse) dependency calculations
- Parallelized checks
Questions?

Indeed, there are some open questions!

Open issues and questions:
Given a package is updated, all its reverse dependencies are re-built for a binary repository and distributed through all the CRAN mirrors. Sometimes more than 300 packages on a single day, while just a few of them really need to be re-built in binary form. Infrastructure that supports calculation of the necessity of a binary re-built is not yet in place. No mechanism is in place to make `update.packages()` collect such (required) rebuilds.

Uwe Ligges et al.: Prospects and Challenges for CRAN useR! 2010, Gaithersburg
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- ... while just a few of them really need to be re-built in binary form
- Infrastructure that supports calculation of the necessity of a binary re-built not yet in place
- No mechanism in place to make `update.packages()` collect such (required) rebuilds
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Open issues and questions:

- Some better database like system for each library (no need to parse thousands of DESCRIPTION files) / each repository
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- Moving rest of perl code to R (as we have seen a speed gain when porting the INSTALL script from perl to R), ‘Rd2 parser’ (Duncan Murdoch), and hopefully also for the ported check scripts
- Being much stricter in CRAN maintenance
References


