CrossdateR:

a visualization tool to assess the quality of crossdated tree-ring series

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1 What is CrossdateR?

CrossdateR is a loose collection of functions, which help to visually assess the quality of crossdated tree-ring series and to detect the location of missing and overlapping tree rings. Although summarizing statistics such as correlation coefficients are the base on which crossdating results rely on, dendrochronologists should always visually check if the crossdated tree-ring series agree with the master chronology. In many cases, it is useful to see graphic plots to understand why for example some segments do not crossdate

well. In addition, narrowing down the location of missing or overlapping tree rings is often a cumbersome task using segmented correlation coefficients; graphic plots will make your life easier. The functions that come with CrossdateR are meant to be used as a visual extension to the program COFECHA (Holmes, 1983; Grissino-Mayer, 2001) and the Dendrochronology Program Library (DPL), written by Richard L. Holmes and Edward R. Cook.

The graphic functions have been written in R, a highly flexible programming language and environment for statistical computing and graphics[1], which uses a relatively simple syntax. R is Open Source software, free and platform-independent (available for Windows, Linux and Mac OS X). Apart from providing excellent graphic capabilities, R is probably the most advanced statistical software that you can get.

2 Installation

2.1 Installation of R

On the website `http://www.r-project.org` click on 'Download: CRAN' on the left side. Choose one of the CRAN (Comprehensive R Archive Network) mirrors in your area. In the main window, you will see a section with 'Precompiled Binary Distributions'. Alternatively, there is a link 'Software: R Binaries' on the left side of the website. Click on the link that corresponds to your operating system (Linux, Mac OS X, or Windows). In this section, I give some hints on how to install R under Windows and Mac OS X:

- If you want to install 'R for Windows', click on 'base' (Binaries for base distribution). After you read the 'README' file, download the latest installation file ('rwversion.exe', where 'version' is the latest version number; ca. 25 MB). With the R for Windows Setup Wizard, the installation will be a breeze (but first make sure that your hard- and software meets the requirements). When asked to select components, just click the 'Next' button. The entire download and installation process takes just a few minutes. However, if you run into troubles with the installation, then check the 'R for Windows FAQ'[2].

- If you want to install 'R for Mac OS X 10.2.x and above', download the latest disk image (a file called R-version.dmg, where 'version' is the latest version number; ca. 20 MB[3]). Double-click the disk image file and the installer will do the rest for you (but first make sure that your hard- and software meets the requirements). However, if you run into troubles with the installation, then check the 'R for Mac OS X FAQ'[4].

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[1] `http://www.r-project.org`

[2] See the 'Documentation:FAQs' link on the left side of the R website or go to `http://www.stats.ox.ac.uk/pub/R/rw-FAQ.html`

[3] Make sure that you DO NOT install the old Carbon version (file 'rm171.sit'), which can be found under 'MacOS (System 8.6 to 9.1 and MacOS X up to 10.1.x)'.

[4] See the 'Documentation:FAQs' link on the left side of the R website or go for example to `http://stat.ethz.ch/CRAN/bin/macosx/RMacOSX-FAQ.html`.

You do not have to install additional packages for any of the operating systems. There is also the possibility to install R from sources, however, it is recommended to install the binaries.

2.2 Setting the working directory in R

Create anywhere on your computer a directory (e.g. 'crossdating'), where you will save the R workspace and the files that you will import. Open R, i.e., double-click the R icon.

- Under Windows, use the 'File/Change Dir...' menu item to select a new working directory (e.g. the directory 'crossdating').
- Under Mac OS X, use the 'Misc/Change Working Directory...' menu item to select a new working directory (e.g. the directory 'crossdating') or type 'Cmd-D'.

Check if you are in the right working directory by typing `getwd()` (for 'get working directory'; do not forget the parentheses). The path should lead to your working directory. Whenever you want to quit R, type `q()` in the R console (or use the menu). You will be asked, if you want to save the workspace file. You can also save the workspace file during an R session by typing `save.image()` (or use the menu).

Under Windows, a workspace file will be created in your working directory. The next time you want to start in this working directory, just double-click the file. Alternatively, you can double-click the R program icon, change to your working directory, and load the workspace ('File/Load Workspace...'). Under Mac OS X, an invisible workspace file ('.RData') will be created. The next time you want to load this workspace, change to the working directory (see above), and go to the menu 'Workspace/Load Default Workspace' to load the file. Whenever you open an existing workspace, you will see the message `[Previously saved workspace restored]`. R workspaces are interchangeable between operating systems.

2.3 Installation of CrossdateR

Download the zip file 'CrossdateR.zip' from `http://www.colorado.edu/geography/biogeography/crossdater` and unzip the file. The directory 'files' contains the file 'series.raw', which contains the tree-ring series in measurement format, as well as the exported tree-ring series in two-column format. The directory 'master' contains one master chronology 'prlb_spruce2.mas' in two-column format. Move the directories 'files' and 'master' as well as the R script files 'crossdating_v1.3.R' and 'crossdating_functions_v1.3.R' to your working directory (e.g. 'crossdating').

Open R in your working directory as explained above and open the script file 'crossdating_v1.3.R' (Windows: 'File/Open script...' or click on the icon in the R console; Mac OS X: 'File/Open Document...", type 'Cmd-O' or click on the icon with the '.r' in the R console). The first part of the file contains commands that you will use to plot tree-ring series, the second part ('Other useful functions') contains additional functions that you find in this manual or that you might want to use from time to time. You can save any changes in this file. Comments are written after the '#' symbol, for example

```
# Nothing happens when this comment is executed.
```

Load the functions by typing (see the second line in 'crossdating_v1.3.R')[5]

```
source("crossdating_functions_v1.3.R")
```

Execute this command each time you want to load or update the functions in a workspace. You can also copy and paste this line from the script file 'crossdating_v1.3.R' to the R console. More convenient is to just execute the command: Under Windows, go with the cursor somewhere on the command in the script file and type the two keys 'Ctrl-R' (or use the menu: 'Edit/Run line or selection'). Under Mac OS X, highlight the command, and type the two keys 'Cmd-Enter' (or use the menu 'Edit/Execute').

Check if the functions have been loaded using the 'list' command:

```
ls()
```

You should be set up now!

3 How to use CrossdateR

3.1 Importing tree-ring series and master chronologies

Use the FMT program in the DPL program library[6] to export the tree-ring series as raw data. Use the two-column format [option 2: 'Two columns (year, value)'], option 15 in further options ('Each series in separate file'), and use the extension 'raw' to export each tree-ring series in a single file (see some exported tree-ring series in the directory 'files'). Export the tree-ring series directly in the directory 'files' or move them into this directory. Similarly, export the master chronology in two-column format and move it to the directory 'master' (see the example in this directory). To try out the functions, you can use the tree-ring series and the master provided with the zip file.

To import the master chronology 'prlb_spruce2.mas' from the directory 'master', execute the function `import.master.f()`:

```
master <- import.master.f(master.v="master/prlb_spruce2.mas")
```

If you don't see any error messages, then the import was successful and the start and end dates will be printed. The assignment command `<-` evaluates the expression on the right side `import.master.f(master.v="master/prlb_spruce2.mas")` and passes the value to the variable on the left side (`master`) without printing it. The object `master` will be stored in your working directory. You can import several master chronologies by assigning them to different variables, e.g. `master1`, `master2` etc. If you type `master`, you will see start and end dates of the series as well as the values. To get some information on the distribution of the values of the master chronology, just type

[5] The function used is `source` and the argument in parentheses is `"crossdating_functions_v1.3.R"`. If you want to know more about how a function works, just type for example `?source` or `help(source)`.

[6] `http://www.ltrr.arizona.edu/pub/dpl`, see also `http://web.utk.edu/~grissino/software.htm`

```
summary(master)
```

To import a different master chronology, replace 'prlb_spruce2.mas' with the name of the file[7].

To import the tree-ring series 'C044094.raw' and 'C044096.raw' (the 'C' is followed by a zero) from the directory 'files', execute the function `import.series.f()`:

```
series1 <- import.series.f(series.v="files/C044094.raw")
series2 <- import.series.f(series.v="files/C044096.raw")
```

To import different tree-ring series, replace the names 'C044094.raw' and 'C044096.raw' with the names of the files that you want to import. You can also import files without or with a different extension than 'raw' and from a different directory. When you import a series, the start and end date of the time series will be printed in the R console. Because a logarithmic scale will be used to plot the tree-ring series, zeros are replaced with 0.5 and a message will be printed in the console. By default, the units of the raw files are multiplied by 1000 to get units of 0.01 mm. You can easily change the units of the values, by using a division or multiplication factor:

```
series1 <- series1/10
```

Check the time span of the series using `tsp(series1)`. If you need to change the start date, use the function `ts()` and set the argument `start`:

```
series1 <- ts(series1, start=1550)
```

Getting the range of the values of the tree-ring series can be done with

```
range(series1)
range(series2)
```

...or with some more detail on the distribution with

```
summary(series1)
summary(series2)
```

3.2 Plotting tree-ring series

To get a simple line plot of the master series, just type

```
plot(master)
```

in the R console. Since R is an object-oriented programming language, the generic function `plot` knows what it shall do with the object `master`, which is recognized as a time series object (type `class(master)`).

Plotting the distribution of the standardized values of the master chronology can be done by

[7] Make sure that you differentiate between upper- and lower-case letters, R is case sensitive. Always add the extension of the file and don't forget the quotation marks!

```
hist(master)
```

To open a new window, type one of the following commands:

```
x11()       # Windows, Linux or Mac OS X (if R is run in the X11 window)
windows()   # Windows
quartz()    # Mac OS X (if R for Mac OS X Aqua GUI is run)
```

To get a simple line plot of the two tree-ring series in one window, type

```
plot(series1)
lines(series2, col="blue")
```

You find these two functions and other additional functions also in the second section of the script file. We can easily visualize the distribution of the data by typing

```
par(mfrow=c(2,2))
hist(series1); hist(series2)
plot(series1); plot(series2)
```

Plotting several tree-ring series in one window is quite simple:

```
series3 <- import.series.f(series.v="files/C044110.raw")
series4 <- import.series.f(series.v="files/C044112.raw")
series5 <- import.series.f(series.v="files/C044081.raw")
series6 <- import.series.f(series.v="files/C044083.raw")
plot(cbind(series1, series2, series3, series4, series5, series6))
```

Removing objects in the workspace can be done using `rm()`:

```
rm(series3, series4, series5, series6)
```

Now we want to have a closer look at the growth curves. Execute the function `plot1.f()`[8]:

```
plot1.f(series1.c="C044094", series2.c="C044096", master.v=master)
```

Actually, you can use any labels for the arguments `series1.c` and `series2.c`. As long as you consider the order of the arguments (see `args(plot1.f)`), you can also just write:

```
plot1.f("C044094", "C044096", master)
```

[8]Type `plot1.f` without parentheses to see the function or open the file 'crossdating_functions_v1.3.R'. In the beginning of each function, there is a short description on how to use it.

For this example, three windows should open, the first two with four subpanels and the third one with two subpanels. Enlarge the windows to see more details. Each subpanel comprises 51 years. The tick marks on the x axis show years, decades are labelled. If you do not want to see the second series, then type
`plot1.f(series1.c="C044094", series2.c=FALSE, master.v=master)` or just
`plot1.f(series1.c="C044094", master.v=master)`.
The scale of the left y axis of each subpanel is automatically adjusted to the ring width of both tree-ring series and shows the units for the two tree-ring series (0.01 mm) on a logarithmic scale. The right y axis shows the scale for the standardized master chronology. The dotted red horizontal line shows a value of 0, dotted vertical lines show standardized values ≤ -2 SD (standard deviations), dot-dashed vertical lines show standardized values $\geq +2$ SD. If you want to decrease or increase the font size, just change the argument `font.size`, which is set by default to `0.8`. The following example

```
plot1.f(series1.c="C044094", series2.c="C044096",
        master.v=master, font.size=0.7)
```

... would decrease the font size. You can also change the number of years shown in each subpanel by changing the argument `window.size`, which is set by default to 51 years (= `window.size` + 1):

```
plot1.f(series1.c="C044094", series2.c="C044096",
        master.v=master, window.size=30)
```

The minimum window size is 20.

3.3 Identifying missing rings

Graphic plots allow to identify relatively quickly, where missing rings are located. In the following example, the ring in 1872 was removed in the series 'C044094', and the outer part was shifted backward ('C045094'), respectively the inner part was shifted forward ('C046094'). When we crossdate the tree-ring series against a master chronology ('prlb_spruce2.mas') with COFECHA ...

```
PART 5:  CORRELATION OF SERIES BY SEGMENTS:
 ---------------------------------------------------------------------------------------------------
 Correlations of  50-year dated segments, lagged  25 years
 Flags:  A = correlation under   .3281 but highest as dated;  B = correlation higher ...

 Seq Series  Time_span   ... 1650 1675 1700 1725 1750 1775 1800 1825 1850 1875 1900 1925 1950 1975
                         ... 1699 1724 1749 1774 1799 1824 1849 1874 1899 1924 1949 1974 1999 2024
 --- -------- ---------  ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
   1 C044094  1551 2003   ... .69  .66  .68  .71  .69  .64  .67  .71  .69  .74  .72  .70  .76  .69
   2 C044096  1534 2003   ... .72  .70  .67  .63  .50  .55  .74  .69  .63  .70  .70  .60  .50  .47
   ...
   7 C045094  1551 2002   ... .69  .66  .68  .71  .69  .64  .66  .41  .15B .09B .02B .10B-.03B-.05B
   8 C046094  1552 2003   ... .08B .01B .08B-.13B-.06B .02B .02B-.10B .09B .73  .72  .70  .76  .69
   ...
```

... it is clear that the two tree-ring series 'C045094' and 'C046094' have a problem in the segment 1850 – 1899 (parts of the output were omitted). If we crossdate the tree-ring series against other tree-ring series, we see that tree-ring series 'C045094'...

```
=================  ========  ========  ========  ========  ========  ========  ========
          Counted       Corr      Corr      Corr      Corr      Corr      Corr      Corr
Series    Segment   Add  # 1  Add  # 2  Add  # 3  Add  # 4  Add  # 5  Add  # 6 ...
-------- ---------  --------  --------  --------  --------  --------  --------  --------
 ...
C045094  1776 1825     0 .63   132 .40  -210 .38  -205 .38    69 .32   -67 .31   117 .31 ...
C045094  1801 1850     0 .65  -210 .50    69 .43   132 .35    37 .33  -191 .33  -239 .32 ...
C045094  1826 1875     0 .39    25 .38  -121 .34   112 .33  -170 .32   -42 .31   -71 .30 ...
C045094  1851 1900  -277 .37    25 .37  -184 .34    15 .33    80 .32   -42 .31   -32 .29 ...
C045094  1876 1925     1 .69  -197 .39    21 .39    54 .35  -307 .33   -99 .31  -129 .30 ...
C045094  1901 1950     1 .71   -70 .37  -307 .32  -301 .32  -176 .31   -31 .29  -194 .29 ...
C045094  1926 1975     1 .70  -131 .44   -52 .38  -234 .36  -284 .34   -65 .31  -179 .31 ...
C045094  1951 2000     1 .69  -271 .40   -73 .38  -152 .33   -18 .33  -190 .31   -76 .30 ...
C045094  1953 2002  Lag from prior segment   2 years - insufficient
    17 segments  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
Number of segments
      Add No R_av   Add No R_av   Add No R_av   Add No R_av   ...
       +0 11  .64    +1  4  .70   -42  3  .30   +41  3  .32   ...
```

... has a missing ring and that the outer part has to be shifted by 1 year forward. Similarly, series 'C046094' has a missing ring ...

```
=================  ========  ========  ========  ========  ========  ========  ========
          Counted       Corr      Corr      Corr      Corr      Corr      Corr      Corr
Series    Segment   Add  # 1  Add  # 2  Add  # 3  Add  # 4  Add  # 5  Add  # 6  Add  # 7 ...
-------- ---------  --------  --------  --------  --------  --------  --------  --------
...
C046094  1777 1826    -1 .63   131 .40  -211 .38  -206 .38    68 .32   -68 .31   116 .31 ...
C046094  1802 1851    -1 .65  -211 .50    68 .43   131 .35    36 .33  -192 .33  -240 .32 ...
C046094  1827 1876    -1 .39    24 .38  -122 .34   111 .33  -171 .32   -43 .31   -72 .30 ...
C046094  1852 1901  -278 .37    24 .37  -185 .34    14 .33    79 .32   -43 .31   -33 .29 ...
C046094  1877 1926     0 .69  -198 .39    20 .39    53 .35  -308 .33  -100 .31  -130 .30 ...
C046094  1902 1951     0 .71   -71 .37  -308 .32  -302 .32  -177 .31   -32 .29  -195 .29 ...
C046094  1927 1976     0 .70  -132 .44   -53 .38  -235 .36  -285 .34   -66 .31  -180 .31 ...
C046094  1952 2001     0 .69  -272 .40   -74 .38  -153 .33   -19 .33  -191 .31   -77 .30 ...
C046094  1954 2003  Lag from prior segment   2 years - insufficient
    17 segments  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
Number of segments
      Add No R_av   Add No R_av   Add No R_av   Add No R_av ...
       -1 11  .64    +0  4  .70   -43  3  .30   +40  3  .32 ...
```

... and the inner part needs to be shifted backward by 1 year.

We import 'C045094' with

```
series1 <- import.series.f(series.v="files/C045094.raw")
```

Using `plot1.f()`...

```
plot1.f(series1.c="C045094", series2.c="C044096", master.v=master)
```

... we can narrow down the problem to be somewhere between the late 1860s to early 1870s. In this case, we assume that 'C044096' is the second core of the same tree. Since both the master and 'C044096' show a relatively narrow ring in 1872, this is certainly a place that we have to scrutinize further. Additionally, we can use the function `plot2.f()`, which allows to shift 'series1' by k years forward or backward and to constrain the time window that we want to look at:

```
plot2.f(series1.c="C045094", series2.c="C044096", master.v=master,
        shift.c=1, start.c=1840, end.c=1890, abline.c=TRUE)
```

The left y axis shows the scale for the ring widths of 'series1' and 'series2' on a logarithmic scale, and the right y axis shows the scale for the standardized master chronology. Positive values for the argument `shift.c` will shift 'series1' forward, negative values will shift it backward. The arguments `start.c` and `end.c` indicate the beginning and end of the window. The vertical dotted lines can be turned off by setting `abline.c=FALSE`. We can omit the second series by writing `series2.c=FALSE` and/or we can also omit to shift the first series by writing `shift.c=FALSE`. Here too, you can change the font size using the argument `font.size`.

Having a second look at the series reveals in many cases where the problem is: often it is sufficient to remeasure 20 or 30 years of the series (in this case from ca. 1860 to about 1880), import this section as 'series2' and plot it together with 'series1' with `plot2.f()`.

In the last step, we try to virtually insert a ring using the function `plot3.f()`:

```
plot3.f(series1.c="CO45094", series2.c="C044096", ring.insert=1868,
        adjust.c="L", overlap.c=FALSE, master.v=master,
        start.c=1840, end.c=1890, abline.c=TRUE)
```

Since the inner or left part of series 'C045094' is correctly adjusted, we use `adjust.c="L"`, for series 'C046094' we would use `adjust.c="R"`. If you indicate a value for `ring.insert`, always set `overlap.c=FALSE` or omit this argument in the call. Again, changing the font size can be done using the argument `font.size`.

Inserting a ring seems to be a good idea, however, we will have to find the right spot. Comparing different options is the best way to do this. We change the parameter settings `par()` and plot three graphics on one window:

```
par(mfrow=c(3,1))

plot3.f(series1.c="CO45094", series2.c="C044096", ring.insert=1870,
        adjust.c="L", overlap.c=FALSE, master.v=master,
        start.c=1840, end.c=1890, abline.c=TRUE)

plot3.f(series1.c="CO45094", series2.c="C044096", ring.insert=1871,
        adjust.c="L", overlap.c=FALSE, master.v=master,
        start.c=1840, end.c=1890, abline.c=TRUE)

plot3.f(series1.c="CO45094", series2.c="C044096", ring.insert=1872,
        adjust.c="L", overlap.c=FALSE, master.v=master,
        start.c=1840, end.c=1890, abline.c=TRUE)
```

3.4 Identifying overlapping rings

Sometimes, overlapping rings occur in series, for example after breaks. To illustrate this, two rings were inserted in 'C044094' before 1831, and the outer part was shifted forward ('C047094'), respectively the inner part was shifted backward ('C048094').

Using COFECHA, we see that for both tree-ring series, the problem must be somewhere between 1800 and 1849 ...

```
PART 5:  CORRELATION OF SERIES BY SEGMENTS:
 ---------------------------------------------------------------------------------------------------------
 Correlations of  50-year dated segments, lagged  25 years
 Flags:  A = correlation under   .3281 but highest as dated;  B = correlation higher ...

 Seq Series  Time_span   ...  1650 1675 1700 1725 1750 1775 1800 1825 1850 1875 1900 1925 1950 1975
                         ...  1699 1724 1749 1774 1799 1824 1849 1874 1899 1924 1949 1974 1999 2024
 --- -------- ---------  ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
   ...
   9 C047094  1551 2005   ... .69  .66  .68  .71  .69  .64  .28B .07B-.01B .07B .24B .19B-.11B-.12B
  10 C048094  1549 2003   ... .11B .22B .09B-.22B-.28B-.18B .32B .68  .69  .74  .72  .70  .76  .69
  ...
```

... and that the outer part of 'C047094' has to be shifted backward by 2 years ...

```
==================  ========  ========  ========  ========  ========  ========  ========
          Counted       Corr      Corr      Corr      Corr      Corr      Corr      Corr
Series    Segment   Add  # 1  Add  # 2  Add  # 3  Add  # 4  Add  # 5  Add  # 6  Add  # 7 ...
-------- ---------  --------  --------  --------  --------  --------  --------  --------
...
C047094  1701 1750     0 .64    53 .47  -142 .39   198 .38   183 .36  -141 .35    68 .35 ...
C047094  1726 1775     0 .68   124 .37  -142 .37  -103 .34   166 .34    23 .34  -156 .32 ...
C047094  1751 1800     0 .67   -83 .43   -53 .38  -194 .37   112 .36   114 .35   -12 .34 ...
C047094  1776 1825     0 .63   132 .40  -210 .38  -205 .38    69 .32  -152 .31    58 .31 ...
C047094  1801 1850  -191 .49  -216 .42  -157 .36  -185 .34    -2 .32  -239 .32     0 .32 ...
C047094  1826 1875    -2 .63    23 .42   -44 .40   -73 .39  -174 .36  -214 .36    13 .34 ...
C047094  1851 1900    -2 .67   -12 .49    13 .45  -186 .41  -123 .32   -44 .32   -14 .28 ...
C047094  1876 1925    -2 .69  -200 .41    18 .39    51 .37  -310 .35  -251 .31   -61 .30 ...
...
    17 segments  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
Number of segments
      Add No R_av   Add No R_av   Add No R_av   Add No R_av ...
       +0 10  .63    -2  7  .63   -12  3  .38   -83  3  .35 ...
```

... and that for 'C048094', the inner part has to be shifted forward by 2 years:

```
==================  ========  ========  ========  ========  ========  ========  ========
          Counted       Corr      Corr      Corr      Corr      Corr      Corr      Corr ...
Series    Segment   Add  # 1  Add  # 2  Add  # 3  Add  # 4  Add  # 5  Add  # 6  Add  # 7 ...
-------- ---------  --------  --------  --------  --------  --------  --------  --------
 ...
C048094  1699 1748     2 .64    55 .47  -140 .39   200 .38   185 .36  -139 .35    70 .35 ...
C048094  1724 1773     2 .68   126 .37  -140 .37  -101 .34   168 .34    25 .34  -154 .32 ...
C048094  1749 1798     2 .67   -81 .43   -51 .38  -192 .37   114 .36   116 .35   -10 .34 ...
C048094  1774 1823     2 .63   134 .40  -208 .38  -203 .38    71 .32  -150 .31    60 .31 ...
C048094  1799 1848  -189 .49  -214 .42  -155 .36  -183 .34     0 .32  -237 .32     2 .32 ...
C048094  1824 1873     0 .63    25 .42   -42 .40   -71 .39  -172 .36  -212 .36    15 .34 ...
C048094  1849 1898     0 .67   -10 .49    15 .45  -184 .41  -121 .32   -42 .32   -12 .28 ...
C048094  1874 1923     0 .69  -198 .41    20 .39    53 .37  -308 .35  -249 .31   -59 .30 ...
...
     17 segments  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
Number of segments
      Add No R_av   Add No R_av   Add No R_av   Add No R_av ...
       +2 10  .63    +0  7  .63   -10  3  .38   -81  3  .35 ...
```

We import 'C047094' with `import.series.f()` and display it with 'C044096' using `plot1.f()` and `plot2.f()`:

```
plot2.f(series1.c="C047094", series2.c="C044096", master.v=master,
        shift.c=-2, start.c=1800, end.c=1860, abline.c=TRUE)
```

The next step is to display 'C047094' with two overlapping rings between 1831 and 1833:

```
plot3.f(series1.c="C047094", series2.c="C044096", ring.insert=FALSE,
        adjust.c="L", overlap.c=1831:1833, master.v=master,
        start.c=1800, end.c=1860, abline.c=TRUE)
```

If you indicate an overlapping time (`overlap.c`), always set `ring.insert=FALSE` or omit this argument.

3.5 Printing and saving graphics

Once you created a graphic plot, it is simple to print it out: Under Windows, go to the print menu 'File/Print...' or click the printer symbol or use 'Ctr-P', under Mac OS X, go to 'File/Print...' or use 'Cmd-P'. Maybe you will have to change some graphic parameters in R using `par()` and/or use the landscape format in the print menu.

If you want to save a graphic as a file, there are several possibilities (apart from creating screenshots). The most common formats are probably *jpeg*, *pdf*, and *postscript*. Type `?Devices` to find out, which devices are available on your R system.

To create a *jpeg*, type for example

```
jpeg()
par(mfrow=c(3,1))
plot(series1)
lines(series2, col="blue")
dev.off()
```

You will find a file 'Rplot001.jpeg' in your working directory. Under Mac OS X, you can use `jpeg()` only, when you run R in the X11 Window system, but not in the R for Mac OS X Aqua GUI.

In the next example, we want to plot three graphics on one window and export it as a pdf:

```
pdf(pointsize=0.8)
par(mfrow=c(3,1))
plot3.f(series1.c="C047094", series2.c="C044096", ring.insert=FALSE,
        adjust.c="L", overlap.c=1830:1832, master.v=master,
        start.c=1800, end.c=1860, abline.c=TRUE)
plot3.f(series1.c="C047094", series2.c="C044096", ring.insert=FALSE,
        adjust.c="L", overlap.c=1831:1833, master.v=master,
        start.c=1800, end.c=1860, abline.c=TRUE)
plot3.f(series1.c="C047094", series2.c="C044096", ring.insert=FALSE,
        adjust.c="L", overlap.c=1832:1834, master.v=master,
        start.c=1800, end.c=1860, abline.c=TRUE)
dev.off()
```

The output can be found as file 'Rplots.pdf' in the working directory.

Often, it is desirable to get a postscript file. Whenever we want to export more than one window, we have to set the argument `multi.file.out=TRUE` (which is set by default to `FALSE`) in `plot1.f()` and `onefile=FALSE` in `postscript()`:

```
postscript(onefile=FALSE)
plot1.f(series1.c="C044094", series2.c="C044096",
        master.v=master, multi.file.out=TRUE)
dev.off()
```

Three files can be found in the working directory ('Rplot001.ps', 'Rplot002.ps', 'Rplot003.ps'). Similarly, it is also possible to export more than one pdf file using `pdf(onefile=FALSE)`.

4 FAQ (Frequently Asked Questions)

- FAQ 1: Why didn't you write a nice program with windows and a menu?

  Answer 1: Because I wanted to keep the functions as simple and flexible as possible. I want the user to be able to change and extend the functions.

- FAQ 2: I have problems installing and using R. Can you help me?

  Answer 2: No, I do not provide any support related to R. Send your questions to the r-help mailing list[9] or ask somebody in your department, who uses R.

- FAQ 3: How can I change the functions?

  Answer 3: Learn how to use R. Download one of the manuals[10] or get one of the books on R[11] [e.g. Dalgaard (2002), or R/S-Plus, e.g. Venables and Ripley (2002)]. Feel free to adjust the functions to your needs: open the file 'crossdating_functions_v1.3.R', change the function, and copy-and-paste it into the R console or `source` the file 'crossdating_functions_v1.3.R'.

- FAQ 4: What does the name CrossdateR stand for?

  Answer 4: It is a combination of 'to crossdate' and 'R'.

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I want to thank Chaz Gunning, Juan Paritsis, and Tom Veblen for testing the beta version of CrossdateR.

[9] `http://www.r-project.org/mail.html`
[10] `http://cran.r-project.org/manuals.html`
[11] `http://www.r-project.org/doc/bib/R-publications.html`

References

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Epilogue: The functions come with absolutely no warranty. There might be unprecedented situations, when you get an error message or a warning. If you find any bugs, send me an e-mail (provide information on the operating system, R version, CrossdateR version and send me the file that created the problem). If you think that parts of the functions or entire functions might be rewritten using nicer or faster programming code then do so. Also, if you want to adjust or extend the functions to your needs, then feel free. Referring to the author of the original functions would be appreciated.