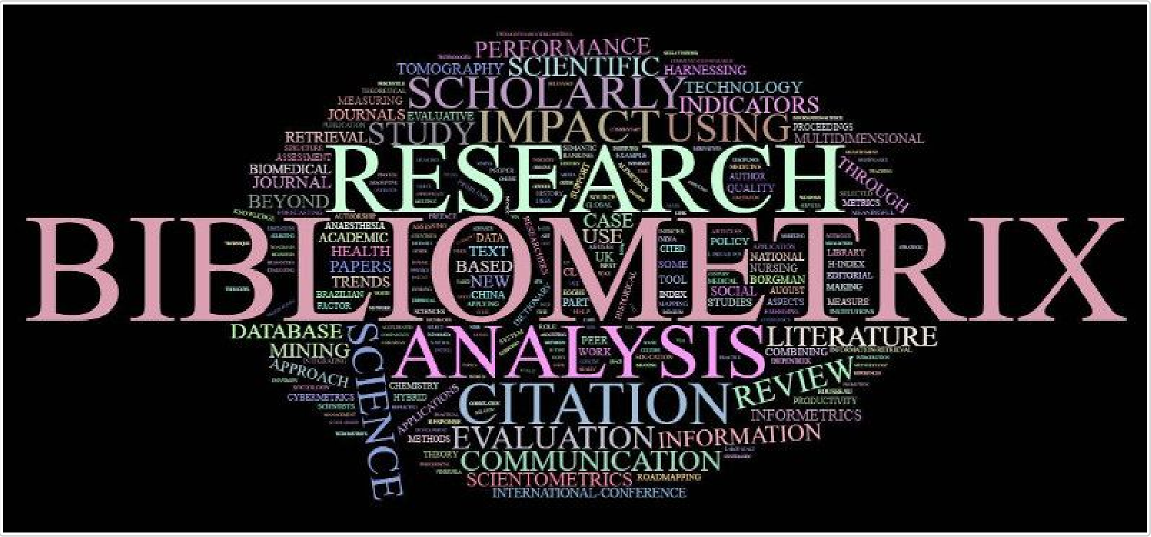
A brief introduction to bibliometrix

Massimo Aria and Corrado Cuccurullo

2019-06-27



bibliometrix

http://www.bibliometrix.org

Latest version

```
## bibliometrix  2.2.1
```

Citation for package ‘bibliometrix’

To cite bibliometrix in publications, please use:

Aria, M. & Cuccurullo, C. (2017) bibliometrix: An R-tool for comprehensive science mapping analysis, Journal of Informetrics, 11(4), pp 959-975, Elsevier.

A BibTeX entry for LaTeX users is

@Article{,

author = {Massimo Aria and Corrado Cuccurullo},

title = {bibliometrix: An R-tool for comprehensive science mapping analysis},

journal = {Journal of Informetrics},

volume = {11},

number = {4},

pages = {959-975},

publisher = {Elsevier},

year = {2017},

url = {https://doi.org/10.1016/j.joi.2017.08.007},

}

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Introduction

bibliometrix package provides a set of tools for quantitative research in bibliometrics and scientometrics.

Bibliometrics turns the main tool of science, quantitative analysis, on itself. Essentially, bibliometrics is the application of quantitative analysis and statistics to publications such as journal articles and their accompanying citation counts. Quantitative evaluation of publication and citation data is now used in almost all scientific fields to evaluate growth, maturity, leading authors, conceptual and intellectual maps, trends of a scientific community.

Bibliometrics is also used in research performance evaluation, especially in university and government labs, and also by policymakers, research directors and administrators, information specialists and librarians, and scholars themselves.

bibliometrix supports scholars in three key phases of analysis:

- Data importing and conversion to R format;
- Bibliometric analysis of a publication dataset;
- Building matrices for co-citation, coupling, collaboration, and co-word analysis. Matrices are the input data for performing network analysis, multiple correspondence analysis, and any other data reduction techniques.

Bibliographic databases

bibliometrix works with data extracted from the four main bibliographic databases: SCOPUS, Clarivate Analytics Web of Science, Cochrane Database of Systematic Reviews (CDSR) and RISmed PubMed/MedLine.

SCOPUS (http://www.scopus.com), founded in 2004, offers a great deal of flexibility for the bibliometric user. It permits to query for different fields, such as titles, abstracts, keywords, references and so on. SCOPUS allows for relatively easy downloading data-queries, although there are some limits on very large results sets with over 2,000 items.

Clarivate Analytics Web of Science (WoS) (http://www.webofknowledge.com), owned by Clarivate Analytics, was founded by Eugene Garfield, one of the pioneers of bibliometrics.
This platform includes many different collections.

Cochrane Database of Systematic Reviews (http://www.cochranelibrary.com/cochrane-database-of-systematic-reviews/index.html) is the leading resource for systematic reviews in health care. The CDSR includes Cochrane Reviews (the systematic reviews) and protocols for Cochrane Reviews as well as editorials. The CDSR also has occasional supplements. The CDSR is updated regularly as Cochrane Reviews are published “when ready” and form monthly issues; see publication schedule.

PubMed comprises more than 28 million citations for biomedical literature from MEDLINE, life science journals, and online books. Citations may include links to full-text content from PubMed Central and publisher websites.

Data acquisition

Bibliographic data may be obtained by querying the SCOPUS or Clarivate Analytics Web of Science (WoS) database by diverse fields, such as topic, author, journal, timespan, and so on.

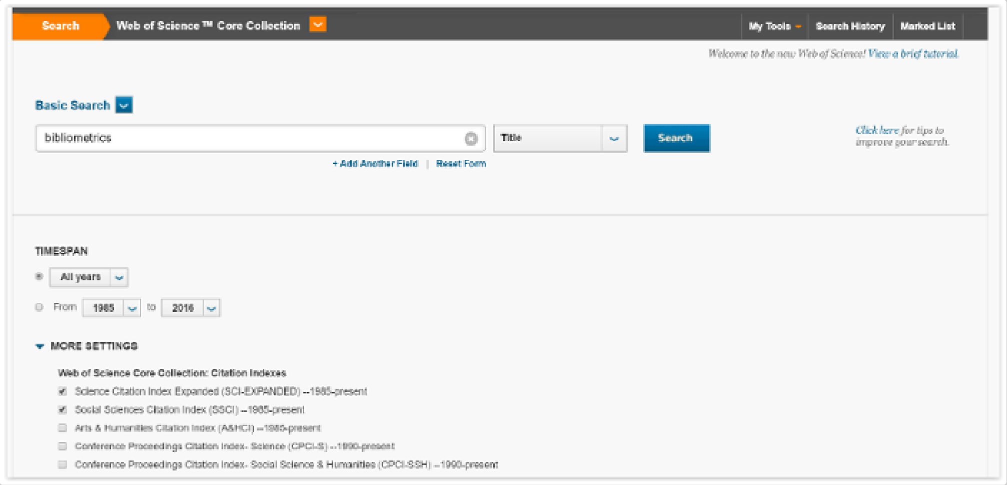
In this example, we show how to download data, querying a term in the manuscript title field.

We choose the generic term “bibliometrics”.

Querying from Clarivate Analytics WoS

At the link http://www.webofknowledge.com, select Web of Science Core Collection database.

Write the keyword “bibliometrics” in the search field and select title from the drop-down menu (see figure 1).


Search
Web of Science ™ Core Collection
My Tools
Search History
Marked List
Welcome to the new Web of Science! View a brief tutorial.
Basic Search
Search
+ Add Another Field | Reset Form
Click here for tips to improve your search.

bibliometrics | Title

TIMESPAN

● All years

○ From 1985 to 2016

MORE SETTINGS

Web of Science Core Collection: Citation Indexes

☑ Science Citation Index Expanded (SCI-EXPANDED) --1985-present
☑ Social Sciences Citation Index (SSCI) --1985-present
☐ Arts & Humanities Citation Index (A&HCI) --1985-present
☐ Conference Proceedings Citation Index- Science (CPCI-S) --1990-present
☐ Conference Proceedings Citation Index- Social Science & Humanities (CPCI-SSH) --1990-present

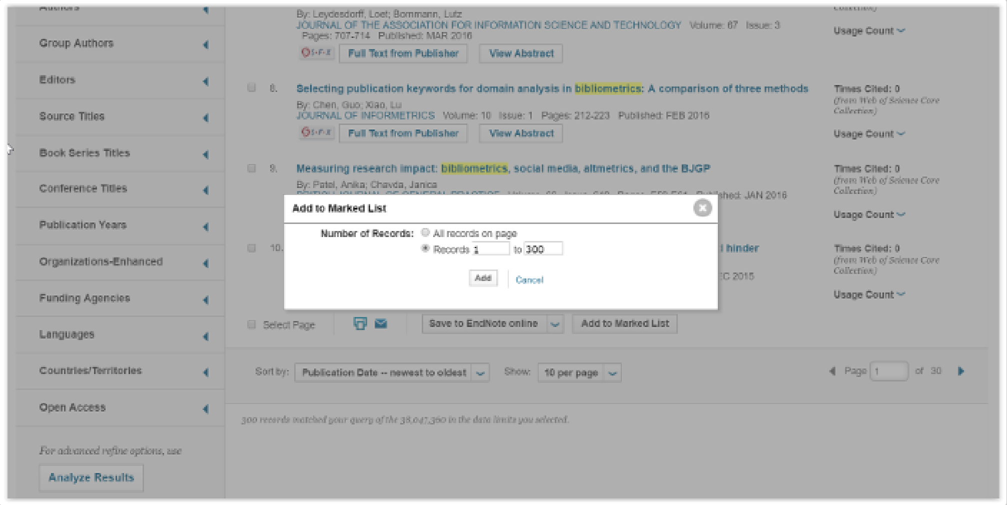
Figure 1

Choose SCI-EXPANDED and SSCI citation indexes.

The search yielded 291 results on May 09, 2016.

Results can be refined using options on the left side of the page (the type of manuscript, source, subject category, etc.).

After refining the query, you can add records to your Marked List by clicking the button “add to marked list” at the end of the page and selecting the records to save (see figure 2).



By: Leydesdorff, Loet; Bornmann, Lutz
JOURNAL OF THE ASSOCIATION FOR INFORMATION SCIENCE AND TECHNOLOGY Volume: 67 Issue: 3 Pages: 707-714 Published: MAR 2016

8. Selecting publication keywords for domain analysis in bibliometrics: A comparison of three methods
By: Chen, Guo; Xiao, Lu
JOURNAL OF INFORMETRICS Volume: 10 Issue: 1 Pages: 212-223 Published: FEB 2016
Times Cited: 0 (from Web of Science Core Collection)

9. Measuring research impact: bibliometrics, social media, altmetrics, and the BJGP
By: Patel, Anika; Chavda, Janica
Published: JAN 2016
Times Cited: 0 (from Web of Science Core Collection)

10. … hinder … C 2015
Times Cited: 0 (from Web of Science Core Collection)

Add to Marked List

Number of Records: ○ All records on page
● Records 1 to 300

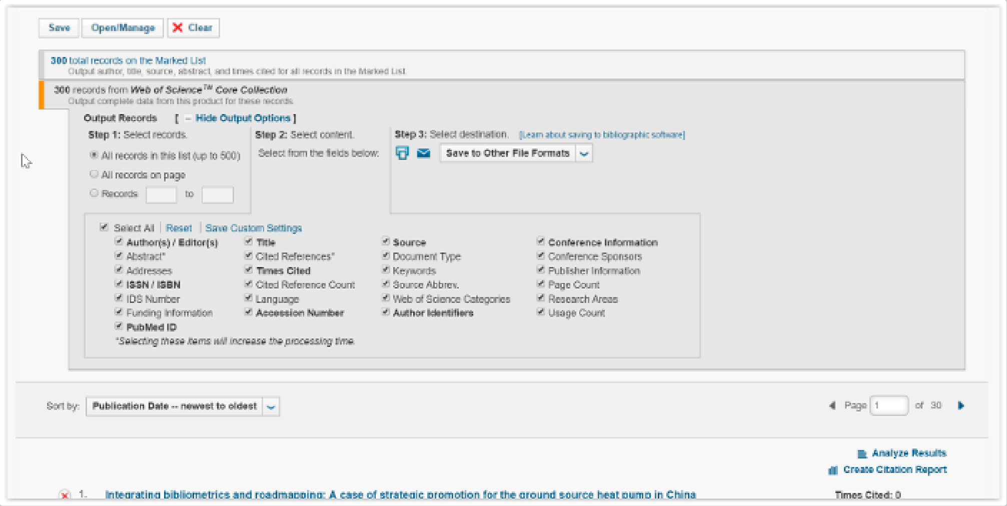
Sort by: Publication Date -- newest to oldest Show: 10 per page Page 1 of 30

300 records matched your query of the 38,047,360 in the data limits you selected.

Figure 2

The Marked List page provides you with a list of publications selected and various means of exporting data.

To export the data you desire, choose the export tool and follow the three intuitive steps (see figure 3).



300 total records on the Marked List
Output author, title, source, abstract, and times cited for all records in the Marked List

300 records from *Web of Science™ Core Collection*
Output complete data from this product for these records.

Output Records [– Hide Output Options]

Step 1: Select records.
● All records in this list (up to 500)
○ All records on page
○ Records ___ to ___

Step 2: Select content.
Select from the fields below:

Step 3: Select destination. [Learn about saving to bibliographic software]
Save to Other File Formats

☑ Select All | Reset | Save Custom Settings

☑ Author(s) / Editor(s)
☑ Abstract*
☑ Addresses
☑ ISSN / ISBN
☑ IDS Number
☑ Funding Information
☑ PubMed ID
☑ Title
☑ Cited References*
☑ Times Cited
☑ Cited Reference Count
☑ Language
☑ Accession Number
☑ Source
☑ Document Type
☑ Keywords
☑ Source Abbrev.
☑ Web of Science Categories
☑ Author Identifiers
☑ Conference Information
☑ Conference Sponsors
☑ Publisher Information
☑ Page Count
☑ Research Areas
☑ Usage Count

*Selecting these items will increase the processing time.

Sort by: Publication Date -- newest to oldest

Page 1 of 30

1. Integrating bibliometrics and roadmapping: A case of strategic promotion for the ground source heat pump in China

Times Cited: 0

Figure 3

The export tool allows you to select the diverse fields to save. So, select the fields you are interested in (for example all the available data about marked records).

To download an export file, in an appropriate format for the *bibliometrix* package, make sure to select the option "**Save to Other File Formats**" and choose Bibtex or Plain Text.

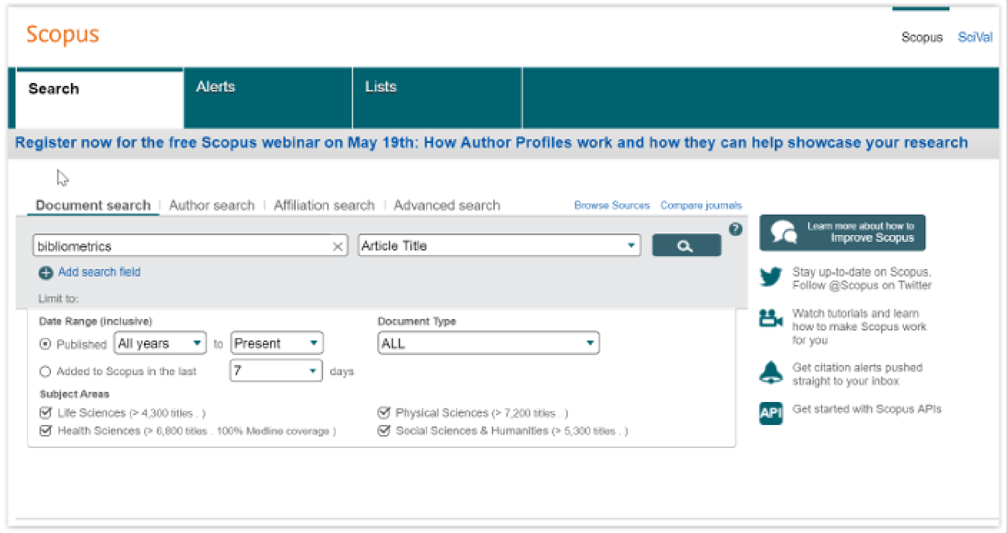
The WoS platform permits to export only 500 records at a time.

The Clarivate Analytics Web of Science export tool creates an export file with a default name "savedrecs" with an extension ".txt" or ".bib" for plain text or BibTeX format respectively. Export files can be separately stored.

Querying from SCOPUS

The access to SCOPUS is via http://www.scopus.com.

To find all articles whose title includes the term "bibliometrics", simply write this keyword in the field and select "Article Title" (see figure 4)



Register now for the free Scopus webinar on May 19th: How Author Profiles work and how they can help showcase your research

bibliometrics — Article Title

Limit to:

Date Range (inclusive)
● Published All years to Present
○ Added to Scopus in the last 7 days

Document Type
ALL

Subject Areas
☑ Life Sciences (> 4,300 titles .)
☑ Health Sciences (> 6,800 titles . 100% Medline coverage)
☑ Physical Sciences (> 7,200 titles .)
☑ Social Sciences & Humanities (> 5,300 titles .)

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Watch tutorials and learn how to make Scopus work for you

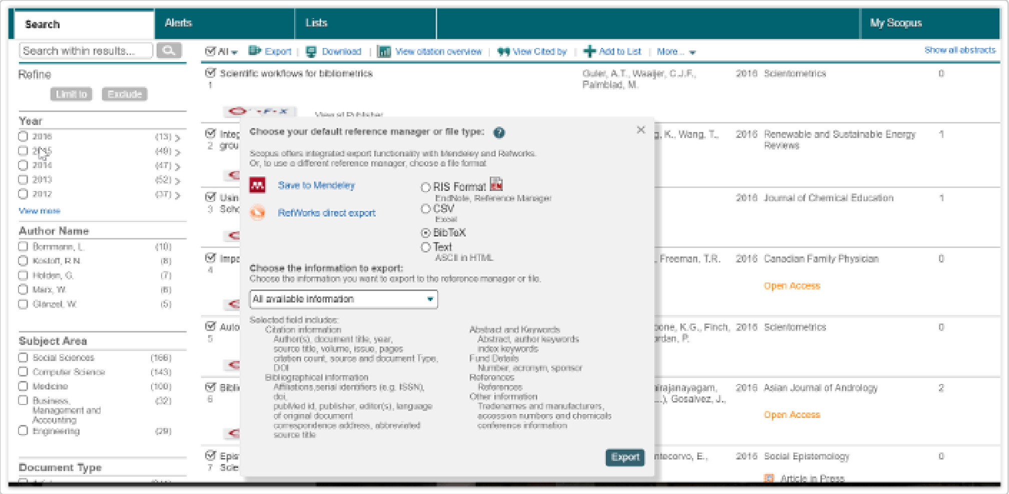
Get citation alerts pushed straight to your inbox

Get started with Scopus APIs

Figure 4

The search yielded 414 results on May 09, 2016.

You can download the references (up to 2,000 full records) by checking the 'Select All' box and clicking on the link 'Export'. Choose the file type "BibTeX export" and "all available information" (see figure 5).



Choose your default reference manager or file type:

Scopus offers integrated export functionality with Mendeley and Refworks.
Or, to use a different reference manager, choose a file format

○ RIS Format
EndNote, Reference Manager
○ CSV
Excel
● BibTeX
○ Text
ASCII in HTML

Choose the information to export:
Choose the information you want to export to the reference manager or file.

All available information

Selected field includes:
Citation information
Author(s), document title, year, source title, volume, issue, pages citation count, source and document Type, DOI
Bibliographical information
Affiliations,serial identifiers (e.g. ISSN), doi, pubMed id, publisher, editor(s), language of original document correspondence address, abbreviated source title
Abstract and Keywords
Abstract, author keywords index keywords
Fund Details
Number, acronym, sponsor
References
References
Other information
Tradenames and manufacturers, accession numbers and chemicals conference information

Figure 5

The SCOPUS export tool creates an export file with the default name “scopus.bib”.

bibliometrix installation

Download and install the most recent version of R (cran.r-project.org)

Download and install the most recent version of Rstudio (http://www.rstudio.com)

Open Rstudio, in the console window, digit:

install.packages(“bibliometrix”, dependencies=TRUE) ### installs bibliometrix package and dependencies

```
library(bibliometrix)   ### load bibliometrix package
```

```
## To cite bibliometrix in publications, please use:
## 
## Aria, M. & Cuccurullo, C. (2017) bibliometrix: An R-tool for comprehensive science mapping
analysis, Journal of Informetrics, 11(4), pp 959-975, Elsevier.
## 
## 
## http:\\www.bibliometrix.org
## 
## 
## To start with the shiny web-interface, please digit:
## biblioshiny()
```

Data loading and converting

The export file can be read by R using the function *readFiles*:

```
D <- readFiles("http://www.bibliometrix.org/datasets/savedrecs.bib")
```

D is a large character vector. *readFiles* argument contains the name of files downloaded from SCOPUS, Clarivate Analytics WOS, or Cochrane CDSR website.

The function *readFiles* combines all the text files onto a single large character vector. Furthermore, the format is converted into UTF-8.

es. D <- readFiles(“file1.txt”,“file2.txt”, …)

The object D can be converted in a data frame using the function *convert2df*:

```
M <- convert2df(D, dbsource = "isi", format = "bibtex")
```

```
## 
## Converting your isi collection into a bibliographic dataframe
## 
## Articles extracted   100
## Articles extracted   200
## Articles extracted   291
## Done!
## 
## 
## Generating affiliation field tag AU_UN from C1:  Done!
```

convert2df creates a bibliographic data frame with cases corresponding to manuscripts and variables to Field Tag in the original export file.

convert2df accepts two additional arguments: *dbsource* and *format*.

The argument *dbsource* indicates from which database the collection has been downloaded.

It can be:

- "isi" (for Clarivate Analytics Web of Science database),
- "scopus" (for SCOPUS database),
- "pubmed" (for PubMed/Medline database),
- "cochrane" (for Cochrane database of systematic reviews).

The argument *format* indicates the file format of the imported collection. It can be "plaintext" or "bibtex" for WOS collection and mandatorily "bibtext" for SCOPUS collection. The argument is ignored if the collection comes from Pubmed or Cochrane.

Each manuscript contains several elements, such as authors' names, title, keywords and other information. All these elements constitute the bibliographic attributes of a document, also called metadata.

Data frame columns are named using the standard Clarivate Analytics WoS Field Tag codify.

The main field tags are:

Field Tag	Description
AU	Authors
TI	Document Title
SO	Publication Name (or Source)
JI	ISO Source Abbreviation
DT	Document Type
DE	Authors' Keywords
ID	Keywords associated by SCOPUS or ISI database
AB	Abstract
C1	Author Address
RP	Reprint Address
CR	Cited References
TC	Times Cited
PY	Year
SC	Subject Category
UT	Unique Article Identifier
DB	Bibliographic Database

For a complete list of field tags see http://www.bibliometrix.org/documents/Field_Tags_bibliometrix.pdf

Bibliometric Analysis

The first step is to perform a descriptive analysis of the bibliographic data frame.

The function *biblioAnalysis* calculates main bibliometric measures using this syntax:

```
results <- biblioAnalysis(M, sep = ";")
```

The function *biblioAnalysis* returns an object of class "bibliometrix".

An object of class "bibliometrix" is a list containing the following components:

List element	Description
Articles	the total number of manuscripts
Authors	the authors' frequency distribution
AuthorsFrac	the authors' frequency distribution (fractionalized)
FirstAuthors	corresponding author of each manuscript
nAUperPaper	the number of authors per manuscript
Appearances	the number of author appearances
nAuthors	the number of authors
AuMultiAuthoredArt	the number of authors of multi-authored articles
MostCitedPapers	the list of manuscripts sorted by citations

List element	Description
Years	publication year of each manuscript
FirstAffiliation	the affiliation of the corresponding author
Affiliations	the frequency distribution of affiliations (of all co-authors for each paper)
Aff_frac	the fractionalized frequency distribution of affiliations (of all co-authors for each paper)
CO	the affiliation country of the corresponding author
Countries	the affiliation countries' frequency distribution
CountryCollaboration	the intra-country (SCP) and inter-country (MCP) collaboration indices
TotalCitation	the number of times each manuscript has been cited
TCperYear	the yearly average number of times each manuscript has been cited
Sources	the frequency distribution of sources (journals, books, etc.)
DE	the frequency distribution of authors' keywords
ID	the frequency distribution of keywords associated to the manuscript by SCOPUS and Thomson Reuters' ISI Web of Knowledge databases

Functions *summary* and *plot*

To summarize main results of the bibliometric analysis, use the generic function *summary*. It displays main information about the bibliographic data frame and several tables, such as annual scientific production, top manuscripts per number of citations, most productive authors, most productive countries, total citation per country, most relevant sources (journals) and most relevant keywords.

Main information table describes the collection size in terms of number of documents, number of authors, number of sources, number of keywords, timespan, and average number of citations.

Furthermore, many different co-authorship indices are shown. In particular, the **Authors per Article index** is calculated as the ratio between the total number of articles and the total number of authors. The **Co-Authors per Articles index** is calculated as the average number of co-authors per article. In this case, the index takes into account the author appearances while for the "authors per article" an author, even if he has published more than one article, is counted only once. For that reasons, *Authors per Article index* $\geq$ *Co-authors per Article index*.

The **Collaboration Index** (CI) is calculated as Total Authors of Multi-Authored Articles/Total Multi-Authored Articles (Elango and Rajendran, 2012; Koseoglu, 2016). In other word, the Collaboration Index is a Co-authors per Article index calculated only using the multi-authored article set.

Elango, B., & Rajendran, P. (2012). Authorship trends and collaboration pattern in the marine sciences literature: a scientometric study. International Journal of Information Dissemination and Technology, 2(3), 166.

Koseoglu, M. A. (2016). Mapping the institutional collaboration network of strategic management research: 1980–2014. Scientometrics, 109(1), 203-226.

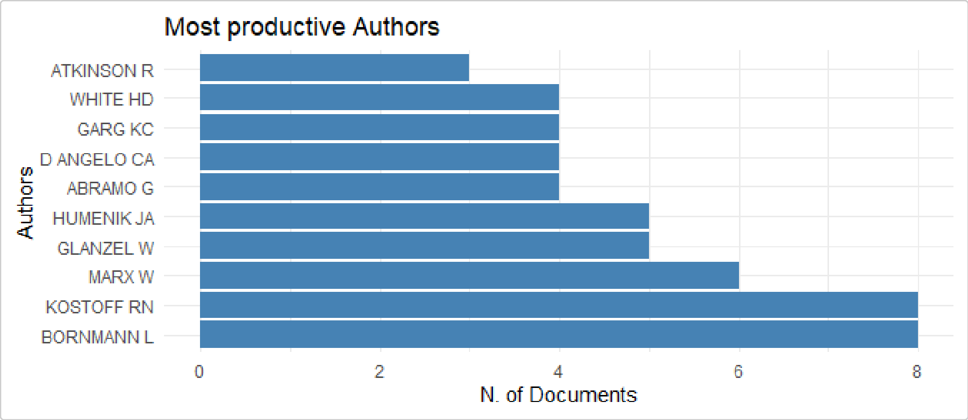
summary accepts two additional arguments. *k* is a formatting value that indicates the number of rows of each table. *pause* is a logical value (TRUE or FALSE) used to allow (or not) pause in screen scrolling. Choosing k=10 you decide to see the first 10 Authors, the first 10 sources, etc.

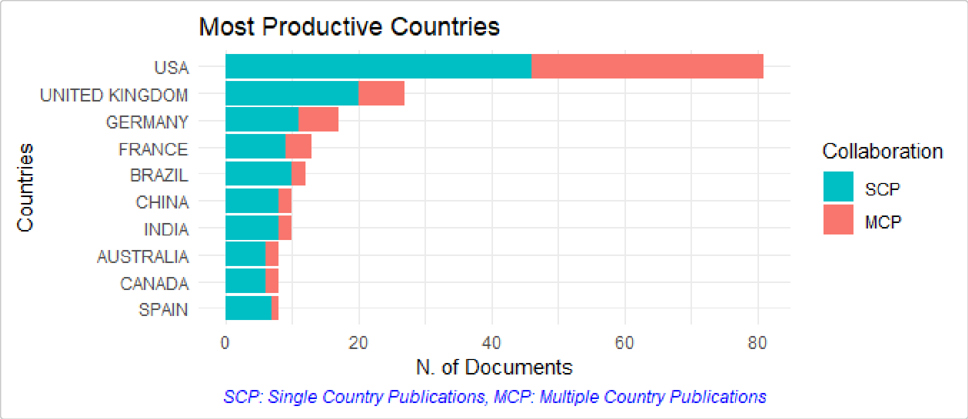
```
options(width=100)
S <- summary(object = results, k = 10, pause = FALSE)
```

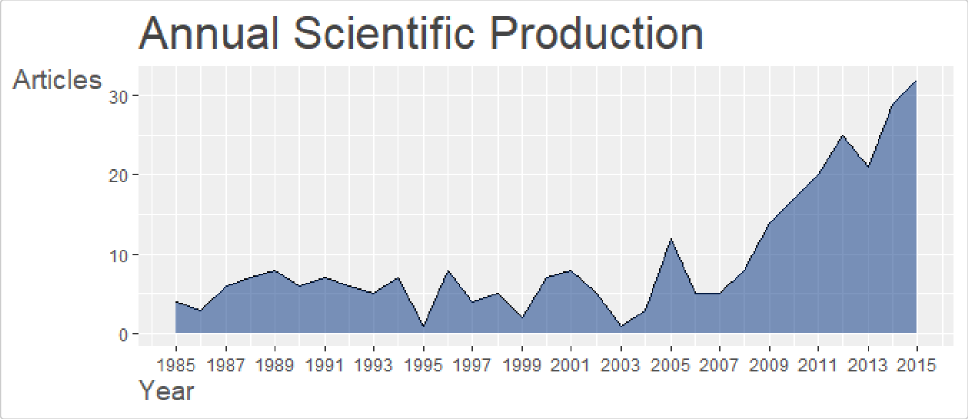
```
## 
## 
## Main Information about data
## 
##  Documents                             291
##  Sources (Journals, Books, etc.)       141
##  Keywords Plus (ID)                    463
##  Author's Keywords (DE)                339
##  Period                                1985 - 2015
##  Average citations per documents       11.73
## 
##  Authors                               535
##  Author Appearances                    647
##  Authors of single-authored documents  121
##  Authors of multi-authored documents   414
##  Single-authored documents             144
## 
##  Documents per Author                  0.544
##  Authors per Document                  1.84
##  Co-Authors per Documents              2.22
##  Collaboration Index                   2.82
## 
##  Document types
##  ART EXHIBIT REVIEW              1
##  ARTICLE                         160
##  ARTICLE, PROCEEDINGS PAPER      7
##  BIOGRAPHICAL-ITEM               1
##  BOOK REVIEW                     32
##  CORRECTION, ADDITION            1
##  EDITORIAL MATERIAL              41
##  LETTER                          16
##  MEETING ABSTRACT                4
##  NOTE                            3
##  REVIEW                          25
##
##
## Annual Scientific Production
##
##  Year    Articles
##     1985        4
##     1986        3
##     1987        6
##     1988        7
##     1989        8
##     1990        6
##     1991        7
##     1992        6
##     1993        5
##     1994        7
##     1995        1
##     1996        8
##     1997        4
##     1998        5
##     1999        2
##     2000        7
##     2001        8
##     2002        5
##     2003        1
##     2004        3
##     2005       12
##     2006        5
##     2007        5
##     2008        8
##     2009       14
##     2010       17
##     2011       20
##     2012       25
##     2013       21
##     2014       29
##     2015       32
##
## Annual Percentage Growth Rate 7.177346
##
##
## Most Productive Authors
##
##    Authors        Articles Authors        Articles Fractionalized
## 1     BORNMANN L         8     BORNMANN L                    4.67
## 2     KOSTOFF RN         8     WHITE HD                      3.50
## 3     MARX W             6     MARX W                        3.17
## 4     GLANZEL W          5     ATKINSON R                    3.00
## 5     HUMENIK JA         5     BROADUS RN                    3.00
## 6     ABRAMO G           4     CRONIN B                      3.00
## 7     D ANGELO CA        4     BORGMAN CL                    2.50
## 8     GARG KC            4     MCCAIN KW                     2.50
## 9     WHITE HD           4     PERITZ BC                     2.50
## 10    ATKINSON R         3     KOSTOFF RN                    2.10
##
##
## Top manuscripts per citations
##
##                                    Paper           TC TCperYear
## 1  DAIM TU, 2006, TECHNOL FORECAST SOC CHANG     211     16.23
## 2  WHITE HD, 1989, ANNU REV INFORM SCI TECHNOL   196      6.53
## 3  BORGMAN CL, 2002, ANNU REV INFORM SCI TECHNOL 192     11.29
## 4  WEINGART P, 2005, SCIENTOMETRICS              151     10.79
## 5  NARIN F, 1994, SCIENTOMETRICS                 141      5.64
## 6  CRONIN B, 2001, J INF SCI                     129      7.17
## 7  CHEN YC, 2011, SCIENTOMETRICS                 101     12.62
## 8  HOOD WW, 2001, SCIENTOMETRICS                  71      3.94
## 9  D'ANGELO CA, 2011, J AM SOC INF SCI TECHNOL    64      8.00
## 10 NARIN F, 1994, EVAL REV                        62      2.48
## 
## 
## Corresponding Author's Countries
## 
##           Country Articles   Freq SCP MCP MCP_Ratio
## 1  USA                  81 0.3057  46  35     0.432
## 2  UNITED KINGDOM       27 0.1019  20   7     0.259
## 3  GERMANY              17 0.0642  11   6     0.353
## 4  FRANCE               13 0.0491   9   4     0.308
## 5  BRAZIL               12 0.0453  10   2     0.167
## 6  CHINA                10 0.0377   8   2     0.200
## 7  INDIA                10 0.0377   8   2     0.200
## 8  AUSTRALIA             8 0.0302   6   2     0.250
## 9  CANADA                8 0.0302   6   2     0.250
## 10 SPAIN                 8 0.0302   7   1     0.125
## 
## 
## SCP: Single Country Publications
## 
## MCP: Multiple Country Publications
## 
## 
## Total Citations per Country
## 
##      Country      Total Citations Average Article Citations
## 1  USA                       1831                     22.60
## 2  GERMANY                    330                     19.41
## 3  ITALY                      163                     32.60
## 4  AUSTRALIA                  134                     16.75
## 5  UNITED KINGDOM             125                      4.63
## 6  CANADA                     111                     13.88
## 7  INDIA                       85                      8.50
## 8  IRAN                        74                     37.00
## 9  SPAIN                       73                      9.12
## 10 BELGIUM                     70                     10.00
## 
## 
## Most Relevant Sources
## 
##                                                             Sources        Articles
## 1  SCIENTOMETRICS                                                                49
## 2  JOURNAL OF THE AMERICAN SOCIETY FOR INFORMATION SCIENCE AND TECHNOLOGY       14
## 3  JOURNAL OF THE AMERICAN SOCIETY FOR INFORMATION SCIENCE                       8
## 4  JOURNAL OF DOCUMENTATION                                                      6
## 5  JOURNAL OF INFORMATION SCIENCE                                                6
## 6  JOURNAL OF INFORMETRICS                                                       6
## 7  BRITISH JOURNAL OF ANAESTHESIA                                                5
## 8  LIBRI                                                                         5
## 9  SOCIAL WORK IN HEALTH CARE                                                    5
## 10 TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE                                   5
## 
## 
## Most Relevant Keywords
## 
##    Author Keywords (DE)      Articles Keywords-Plus (ID)     Articles
## 1      BIBLIOMETRICS               62    SCIENCE                   38
## 2      CITATION ANALYSIS           12    INDICATORS                24
## 3      SCIENTOMETRICS               7    IMPACT                    23
## 4      INFORMATION RETRIEVAL        6    CITATION ANALYSIS         18
## 5      H INDEX                      5    CITATION                  16
## 6      IMPACT FACTOR                5    H INDEX                   13
## 7      PEER REVIEW                  5    JOURNALS                  13
## 8      CITATIONS                    4    PUBLICATION               11
## 9      IMPACT FACTORS               4    GOOGLE SCHOLAR            10
## 10     NURSING                      4    INFORMATION SCIENCE       10
```

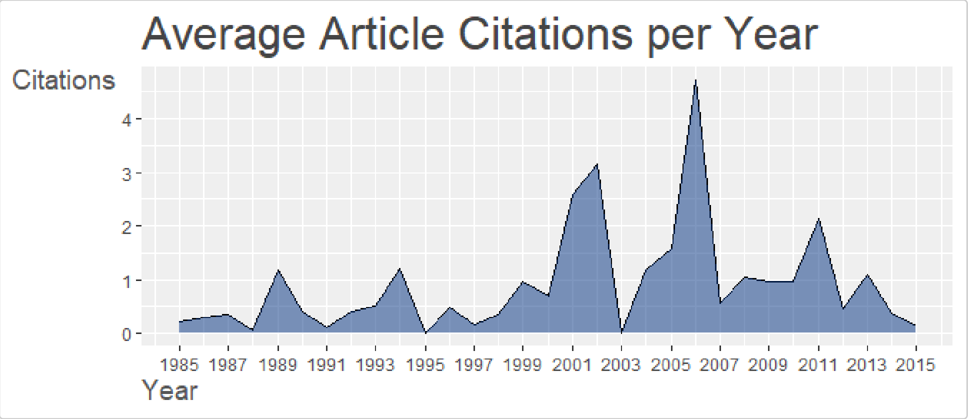
Some basic plots can be drawn using the generic function :

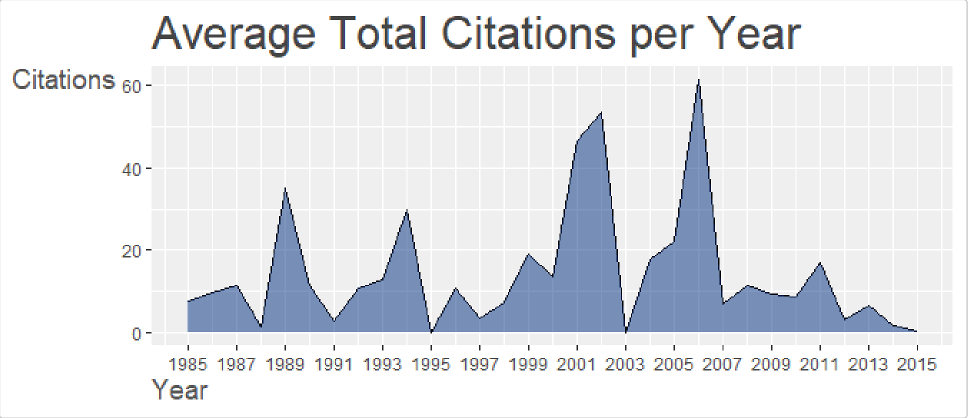
```
plot(x = results, k = 10, pause = FALSE)
```


Most productive Authors
Authors
ATKINSON R
WHITE HD
GARG KC
D ANGELO CA
ABRAMO G
HUMENIK JA
GLANZEL W
MARX W
KOSTOFF RN
BORNMANN L
0
2
4
6
8
N. of Documents


Most Productive Countries
Countries
USA
UNITED KINGDOM
GERMANY
FRANCE
BRAZIL
CHINA
INDIA
AUSTRALIA
CANADA
SPAIN
0
20
40
60
80
N. of Documents
Collaboration
SCP
MCP
SCP: Single Country Publications, MCP: Multiple Country Publications


Annual Scientific Production
Articles
30
20
10
0
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Year





Analysis of Cited References

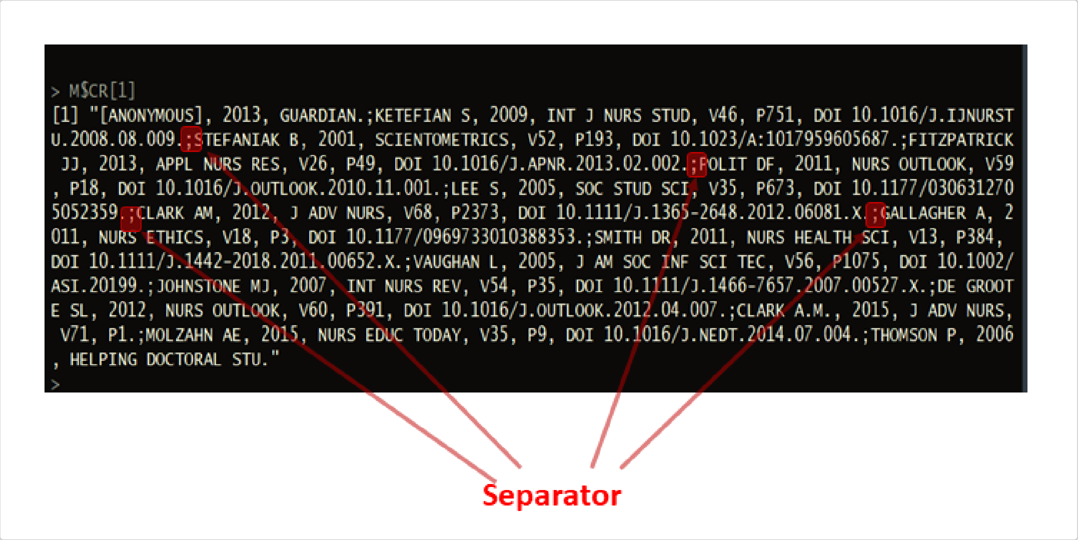
The function *citations* generates the frequency table of the most cited references or the most cited first authors (of references).

For each manuscript, cited references are in a single string stored in the column "CR" of the data frame.

For a correct extraction, you need to identify the separator field among different references, used by ISI or SCOPUS database. Usually, the default separator is ";" or `".  "` (a dot with double space).

```
# M$CR[1]
```

The figure shows the reference string of the first manuscript. In this case, the separator field is `sep = ";"`.



```
> M$CR[1]
[1] "[ANONYMOUS], 2013, GUARDIAN.;KETEFIAN S, 2009, INT J NURS STUD, V46, P751, DOI 10.1016/J.IJNURST
U.2008.08.009.;STEFANIAK B, 2001, SCIENTOMETRICS, V52, P193, DOI 10.1023/A:1017959605687.;FITZPATRICK
 JJ, 2013, APPL NURS RES, V26, P49, DOI 10.1016/J.APNR.2013.02.002.;POLIT DF, 2011, NURS OUTLOOK, V59
, P18, DOI 10.1016/J.OUTLOOK.2010.11.001.;LEE S, 2005, SOC STUD SCI, V35, P673, DOI 10.1177/030631270
5052359.;CLARK AM, 2012, J ADV NURS, V68, P2373, DOI 10.1111/J.1365-2648.2012.06081.X.;GALLAGHER A, 2
011, NURS ETHICS, V18, P3, DOI 10.1177/0969733010388353.;SMITH DR, 2011, NURS HEALTH SCI, V13, P384,
DOI 10.1111/J.1442-2018.2011.00652.X.;VAUGHAN L, 2005, J AM SOC INF SCI TEC, V56, P1075, DOI 10.1002/
ASI.20199.;JOHNSTONE MJ, 2007, INT NURS REV, V54, P35, DOI 10.1111/J.1466-7657.2007.00527.X.;DE GROOT
E SL, 2012, NURS OUTLOOK, V60, P391, DOI 10.1016/J.OUTLOOK.2012.04.007.;CLARK A.M., 2015, J ADV NURS,
 V71, P1.;MOLZAHN AE, 2015, NURS EDUC TODAY, V35, P9, DOI 10.1016/J.NEDT.2014.07.004.;THOMSON P, 2006
, HELPING DOCTORAL STU."
>
```

Figure 6

To obtain the most frequent cited manuscripts:

```
CR <- citations(M, field = "article", sep = ";")
cbind(CR$Cited[1:10])
```

```
##                                                                           [,1]
## HIRSCH JE, 2005, P NATL ACAD SCI USA, V102, P16569, DOI 10.1073/PNAS.0507655102.   29
## SMALL H, 1973, J AM SOC INFORM SCI, V24, P265, DOI 10.1002/ASI.4630240406.         20
## PRITCHAR.A, 1969, J DOC, V25, P348.                                          17
## DE SOLLA PRICE DJ, 1963, LITTLE SCI BIG SCI.                                 16
## BRADFORD S. C, 1934, ENGINEERING-LONDON, V137, P85.                          13
## GARFIELD E, 2006, JAMA-J AM MED ASSOC, V295, P90, DOI 10.1001/JAMA.295.1.90.  12
## COLE FRANCIS J., 1917, SCI PROGR, V11, P578.                                 10
## DE BELLIS NICOLA, 2009, BIBLIOMETRICS CITATI.                                10
## KESSLER MM, 1963, AM DOC, V14, P10, DOI 10.1002/ASI.5090140103.              10
## MOED H. F., 2005, CITATION ANAL RES EV.                                      10
```

To obtain the most frequent cited first authors:

```
CR <- citations(M, field = "author", sep = ";")
cbind(CR$Cited[1:10])
```

```
##                [,1]
## GARFIELD E      150
## BORNMANN L       92
## SMALL H          66
## CRONIN B         65
## WHITE HD         57
## GLANZEL W        50
## KOSTOFF RN       49
## EGGHE L          44
## LEYDESDORFF L    44
## NARIN F          43
```

The function *localCitations* generates the frequency table of the most local cited authors. Local citations measure how many times an author (or a document) included in this collection have been cited by other authors also in the collection.

To obtain the most frequent local cited authors:

```
#CR <- localCitations(M, sep = ";")
#CR$Authors[1:10,]
#CR$Papers[1:10,]
```

Authors’ Dominance ranking

The function *dominance* calculates the authors’ dominance ranking as proposed by Kumar & Kumar, 2008.

Kumar, S., & Kumar, S. (2008). Collaboration in research productivity in oil seed research institutes of India. In Proceedings of Fourth International Conference on Webometrics, Informetrics and Scientometrics.

Function arguments are: *results* (object of class *bibliometrix*) obtained by *biblioAnalysis*; and *k* (the number of authors to consider in the analysis).

```
DF <- dominance(results, k = 10)
DF
```

```
##         Author Dominance Factor Tot Articles Single-Authored Multi-Authored First-Authored
Rank by Articles Rank by DF
## 1   KOSTOFF RN        1.0000000            8               0              8              8
9          1
## 2     WHITE HD        1.0000000            4               3              1              1
3          1
## 3   BORGMAN CL        1.0000000            3               2              1              1
1          1
## 4     HOLDEN G        1.0000000            3               0              3              3
1          1
## 5   BORNMANN L        0.8333333            8               2              6              5
9          5
## 6     ABRAMO G        0.7500000            4               0              4              3
3          6
## 7      GARG KC        0.7500000            4               0              4              3
3          6
## 8    GLANZEL W        0.6000000            5               0              5              3
7          8
## 9  D ANGELO CA        0.2500000            4               0              4              1
3          9
## 10      MARX W        0.2000000            6               1              5              1
8         10
```

The Dominance Factor is a ratio indicating the fraction of multi-authored articles in which a scholar appears as the first author.

In this example, Kostoff and Holden dominate their research team because they appear as the first authors in all their papers (8 for Kostoff and 3 for Holden).

Authors’ h-index

The h-index is an author-level metric that attempts to measure both the productivity and citation impact of the publications of a scientist or scholar.

The index is based on the set of the scientist’s most cited papers and the number of citations that they have received in other publications.

The function *Hindex* calculates the authors’ H-index or the sources’ H-index and its variants (g-index and m-index) in a bibliographic collection.

Function arguments are: *M* a bibliographic data frame; *field* is character element that defines the unit of analysis in terms of authors (field = “auhtor”) or sources (field = “source”); *elements* a character vector containing the authors’ names (or the sources’ names) for which you want to calculate the H-index. The argument has the form c(“SURNAME1 N”,“SURNAME2 N”,…).

In other words, for each author: surname and initials are separated by one blank space. i.e for the authors ARIA MASSIMO and CUCCURULLO CORRADO, *elements* argument is *elements = c(“ARIA M”, “CUCCURULLO C”)*.

To calculate the h-index of Lutz Bornmann in this collection:

```
indices <- Hindex(M, field = "author", elements="BORNMANN L", sep = ";", years = 10)

# Bornmann's impact indices:
indices$H
```

```
##       Author h_index g_index m_index TC NP PY_start
## 1 BORNMANN L       4       7     0.5 50  8     2012
```

```
# Bornmann's citations
indices$CitationList
```

```
## [[1]]
##                          Authors                        Journal Year TotalCitation
## 2              MARX W;BORNMANN L SOZIALE WELT-ZEITSCHRIFT FUR S 2015             0
## 4       BORNMANN L;LEYDESDORFF L        JOURNAL OF INFORMETRICS 2014             1
## 8 BORNMANN L;BOWMAN BF;BAUER J;M     ZEITSCHRIFT FUR EVALUATION 2012             2
## 3                     BORNMANN L            RESEARCH EVALUATION 2014             3
## 1              BORNMANN L;MARX W        JOURNAL OF INFORMETRICS 2015             5
## 6          BORNMANN L;WILLIAMS R        JOURNAL OF INFORMETRICS 2013            10
## 7              BORNMANN L;MARX W        JOURNAL OF INFORMETRICS 2013            11
## 5                     BORNMANN L JOURNAL OF THE AMERICAN SOCIET 2013            18
```

To calculate the h-index of the first 10 most productive authors (in this collection):

```
authors=gsub(","," ",names(results$Authors)[1:10])

indices <- Hindex(M, field = "author", elements=authors, sep = ";", years = 50)

indices$H
```

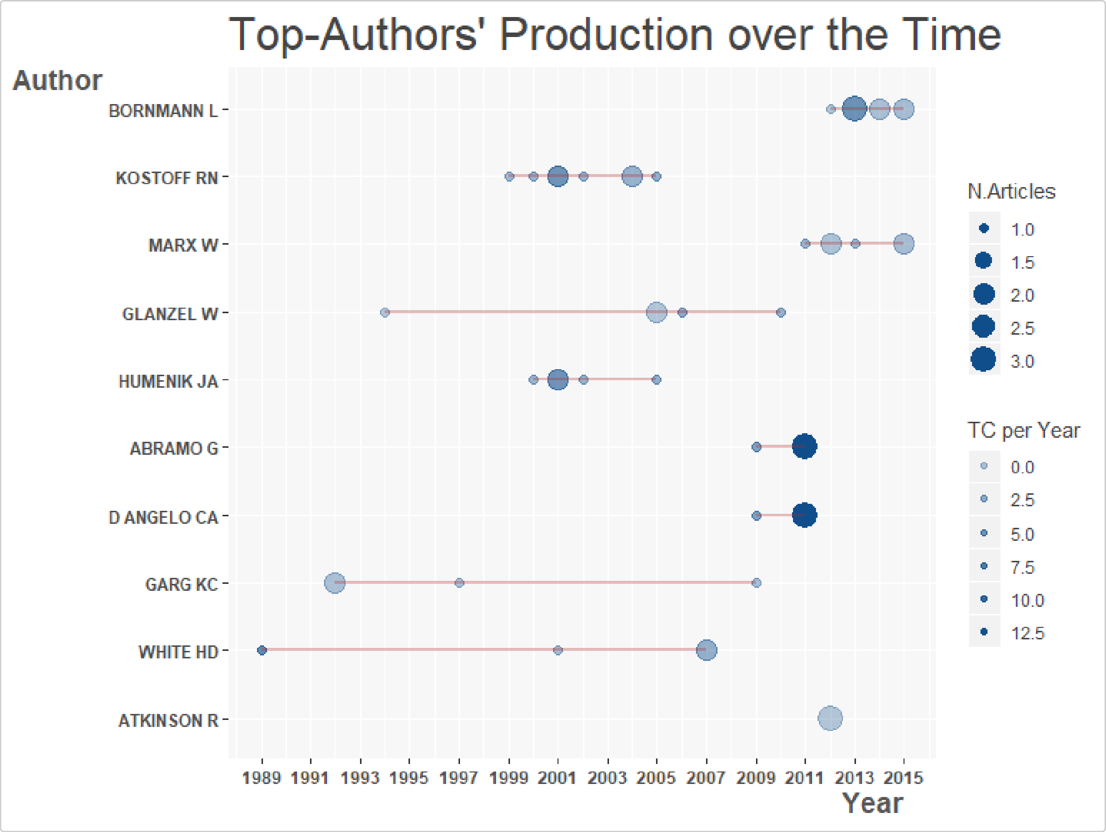
```
##         Author h_index g_index    m_index  TC NP PY_start
## 1   BORNMANN L       4       7 0.50000000  50  8     2012
## 2   KOSTOFF RN       8       8 0.38095238 276  8     1999
## 3       MARX W       3       6 0.33333333  36  6     2011
## 4    GLANZEL W       2       5 0.07692308  64  5     1994
## 5   HUMENIK JA       5       5 0.25000000 213  5     2000
## 6     ABRAMO G       4       4 0.36363636 158  4     2009
## 7  D ANGELO CA       4       4 0.36363636 158  4     2009
## 8      GARG KC       4       4 0.14285714  41  4     1992
## 9     WHITE HD       4       4 0.12903226 248  4     1989
## 10  ATKINSON R       0       0 0.00000000   0  3     2012
```

Top-Authors’ Productivity over the Time

The function *AuthorProdOverTime* calculates and plots the authors’ production (in terms of number of publications, and total citations per year) over the time.

Function arguments are: *M* a bibliographic data frame; *k* is the number of *k* Top Authors; *graph* is a logical. If *graph=TRUE*, the function plots the author production over time graph.

```
topAU <- authorProdOverTime(M, k = 10, graph = TRUE)
```



```
## Table: Author's productivity per year
head(topAU$dfAU)
```

```
##       Author year freq  TC       TCpY
## 1   ABRAMO G 2009    1  43  3.9090909
## 2   ABRAMO G 2011    3 115 12.7777778
## 3 ATKINSON R 2012    3   0  0.0000000
## 4 BORNMANN L 2012    1   2  0.2500000
## 5 BORNMANN L 2013    3  39  5.5714286
## 6 BORNMANN L 2014    2   4  0.6666667
```

```
## Table: Auhtor's documents list
#head(topAU$dfPapersAU)
```

Lotka’s Law coefficient estimation

The function *lotka* estimates Lotka’s law coefficients for scientific productivity (Lotka A.J., 1926).

Lotka’s law describes the frequency of publication by authors in any given field as an inverse square law, where the number of authors publishing a certain number of articles is a fixed ratio to the number of authors publishing a single article. This assumption implies that the theoretical beta coefficient of Lotka’s law is equal to 2.

Using *lotka* function is possible to estimate the Beta coefficient of our bibliographic collection and assess, through a statistical test, the similarity of this empirical distribution with the theoretical one.

```
L <- lotka(results)

# Author Productivity. Empirical Distribution
L$AuthorProd
```

```
##   N.Articles N.Authors        Freq
## 1          1       466 0.871028037
## 2          2        47 0.087850467
## 3          3        13 0.024299065
## 4          4         4 0.007476636
## 5          5         2 0.003738318
## 6          6         1 0.001869159
## 7          8         2 0.003738318
```

```
# Beta coefficient estimate
L$Beta
```

```
## [1] 2.976457
```

```
# Constant
L$C
```

```
## [1] 0.6634829
```

```
# Goodness of fit
L$R2
```

```
## [1] 0.9413535
```

```
# P-value of K-S two sample test
L$p.value
```

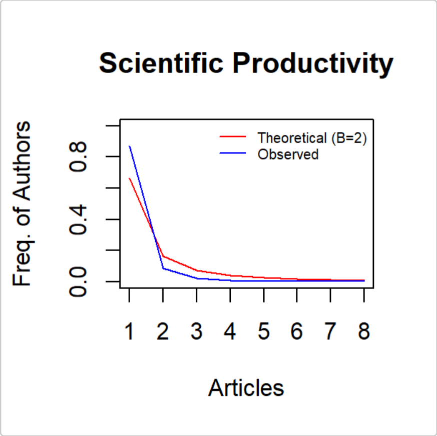
```
## [1] 0.2031888
```

The table L$AuthorProd shows the observed distribution of scientific productivity in our example.

The estimated Beta coefficient is 3.05 with a goodness of fit equal to 0.94. Kolmogorov-Smirnoff two sample test provides a p-value 0.09 that means there is not a significant difference between the observed and the theoretical Lotka distributions.

You can compare the two distributions using *plot* function:

```
# Observed distribution
Observed=L$AuthorProd[,3]

# Theoretical distribution with Beta = 2
Theoretical=10^(log10(L$C)-2*log10(L$AuthorProd[,1]))

plot(L$AuthorProd[,1],Theoretical,type="l",col="red",ylim=c(0, 1), xlab="Articles",ylab="Freq.
  of Authors",main="Scientific Productivity")
lines(L$AuthorProd[,1],Observed,col="blue")
legend(x="topright",c("Theoretical (B=2)","Observed"),col=c("red","blue"),lty =
  c(1,1,1),cex=0.6,bty="n")
```



Bibliographic network matrices

Manuscript’s attributes are connected to each other through the manuscript itself: author(s) to journal, keywords to publication date, etc.

These connections of different attributes generate bipartite networks that can be represented as rectangular matrices (Manuscripts x Attributes).

Furthermore, scientific publications regularly contain references to other scientific works. This generates a further network, namely, co-citation or coupling network.

These networks are analyzed in order to capture meaningful properties of the underlying research system, and in particular to determine the influence of bibliometric units such as scholars and journals.

Bipartite networks

cocMatrix is a general function to compute a bipartite network selecting one of the metadata attributes.

For example, to create a network *Manuscript x Publication Source* you have to use the field tag “SO”:

```
A <- cocMatrix(M, Field = "SO", sep = ";")
```

A is a rectangular binary matrix, representing a bipartite network where rows and columns are manuscripts and sources respectively.

The generic element a_{ij} is 1 if the manuscript i has been published in source j, 0 otherwise.

The $j-th$ column sum a_j is the number of manuscripts published in source j.

Sorting, in decreasing order, the column sums of A, you can see the most relevant publication sources:

```
sort(Matrix::colSums(A), decreasing = TRUE)[1:5]
```

```
##                                                         SCIENTOMETRICS
##                                                                     49
## JOURNAL OF THE AMERICAN SOCIETY FOR INFORMATION SCIENCE AND TECHNOLOGY
##                                                                     14
##               JOURNAL OF THE AMERICAN SOCIETY FOR INFORMATION SCIENCE
##                                                                      8
##                                                JOURNAL OF INFORMETRICS
##                                                                      6
##                                               JOURNAL OF DOCUMENTATION
##                                                                      6
```

Following this approach, you can compute several bipartite networks:

- Citation network

```
# A <- cocMatrix(M, Field = "CR", sep = ".  ")
```

- Author network

```
# A <- cocMatrix(M, Field = "AU", sep = ";")
```

- Country network

Authors’ Countries is not a standard attribute of the bibliographic data frame. You need to extract this information from affiliation attribute using the function *metaTagExtraction*.

```
M <- metaTagExtraction(M, Field = "AU_CO", sep = ";")
# A <- cocMatrix(M, Field = "AU_CO", sep = ";")
```

metaTagExtraction allows to extract the following additional field tags: *Authors’ countries* (`Field = "AU_CO"`); *First Author’s countries* (`Field = "AU_CO"`); *First author of each cited reference* (`Field = "CR_AU"`); *Publication source of each cited reference* (`Field = "CR_SO"`); and *Authors’ affiliations* (`Field = "AU_UN"`).

- Author keyword network

```
# A <- cocMatrix(M, Field = "DE", sep = ";")
```

- Keyword Plus network

```
# A <- cocMatrix(M, Field = "ID", sep = ";")
```

- Etc.

Bibliographic coupling

Two articles are said to be bibliographically coupled if at least one cited source appears in the bibliographies or reference lists of both articles (Kessler, 1963).

A coupling network can be obtained using the general formulation:

$$B = A \times A^T$$

where A is a bipartite network.

Element b_{ij} indicates how many bibliographic couplings exist between manuscripts i and j. In other words, b_{ij} gives the number of paths of length 2, via which one moves from i along the arrow and then to j in the opposite direction.

B is a symmetrical matrix $B = B^T$.

The strength of the coupling of two articles, i and j is defined simply by the number of references that the articles have in common, as given by the element b_{ij} of matrix B.

The function *biblioNetwork* calculates, starting from a bibliographic data frame, the most frequently used coupling networks: Authors, Sources, and Countries.

biblioNetwork uses two arguments to define the network to compute:

- *analysis* argument can be “co-citation”, “coupling”, “collaboration”, or “co-occurrences”.
- *network* argument can be “authors”, “references”, “sources”, “countries”, “universities”, “keywords”, “author_keywords”, “titles” and “abstracts”.

The following code calculates a classical article coupling network:

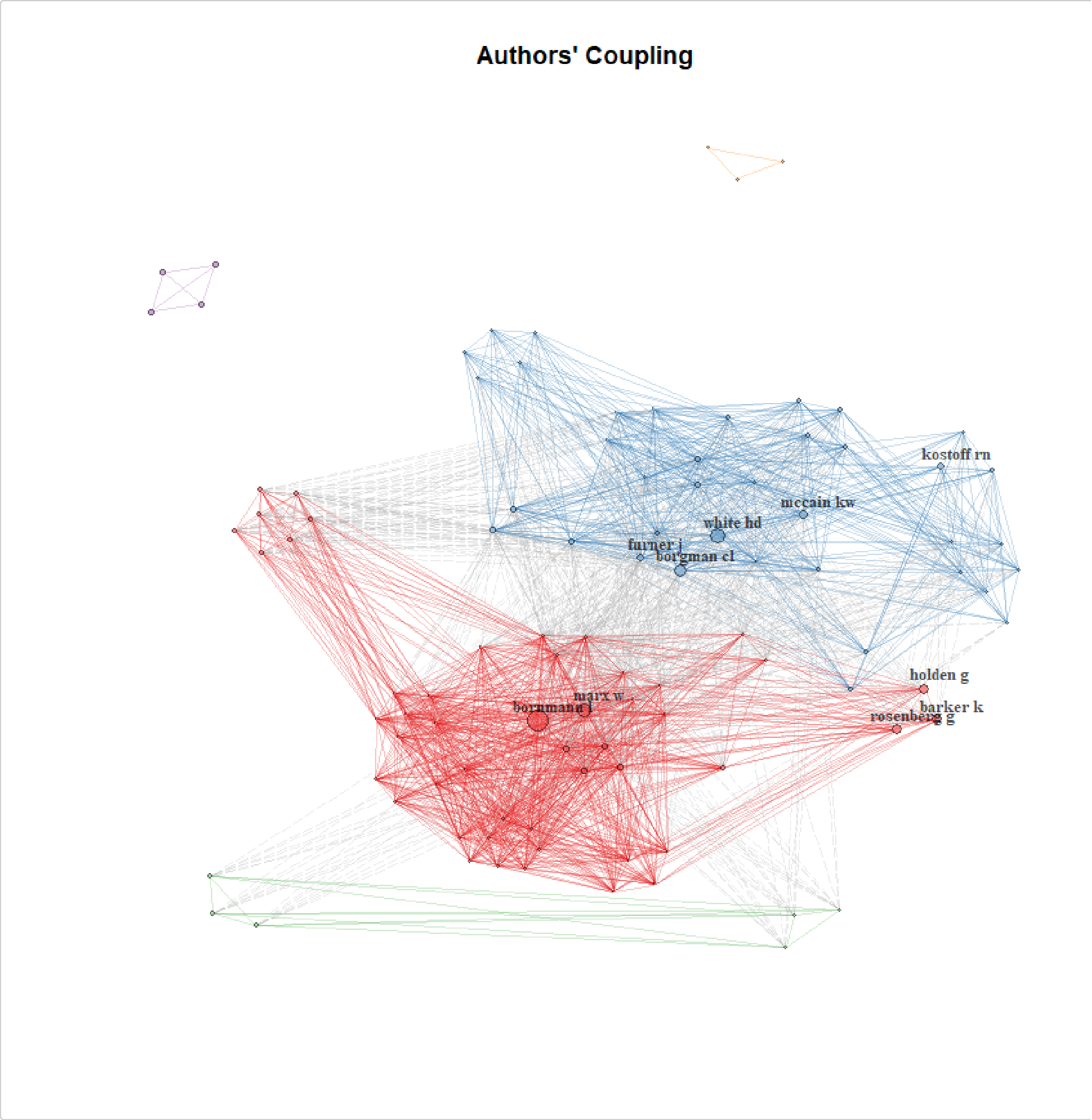
```
# NetMatrix <- biblioNetwork(M, analysis = "coupling", network = "references", sep = ".  ")
```

Articles with only a few references, therefore, would tend to be more weakly bibliographically coupled, if coupling strength is measured simply according to the number of references that articles contain in common.

This suggests that it might be more practical to switch to a relative measure of bibliographic coupling.

normalizeSimilarity function calculates Association strength, Inclusion, Jaccard or Salton similarity among vertices of a network. *normalizeSimilarity* can be recalled directly from *networkPlot()* function using the argument *normalize*.

```
NetMatrix <- biblioNetwork(M, analysis = "coupling", network = "authors", sep = ";")

net=networkPlot(NetMatrix,  normalize = "salton", weighted=NULL, n = 100, Title = "Authors'
  Coupling", type = "fruchterman",
  size=5,size.cex=T,remove.multiple=TRUE,labelsize=0.8,label.n=10,label.cex=F)
```



Bibliographic co-citation

We talk about co-citation of two articles when both are cited in a third article. Thus, co-citation can be seen as the counterpart of bibliographic coupling.

A co-citation network can be obtained using the general formulation:

$$C = A^T \times A$$

where A is a bipartite network.

Like matrix B, matrix C is also symmetric. The main diagonal of C contains the number of cases in which a reference is cited in our data frame.

In other words, the diagonal element c_i is the number of local citations of the reference i.

Using the function *biblioNetwork*, you can calculate a classical reference co-citation network:

```
# NetMatrix <- biblioNetwork(M, analysis = "co-citation", network = "references", sep = ".  ")
```

Bibliographic collaboration

Scientific collaboration network is a network where nodes are authors and links are co-authorships as the latter is one of the most well-documented forms of scientific collaboration (Glanzel, 2004).

An author collaboration network can be obtained using the general formulation:

$$AC = A^T \times A$$

where A is a bipartite network *Manuscripts x Authors*.

The diagonal element ac_i is the number of manuscripts authored or co-authored by researcher i.

Using the function *biblioNetwork*, you can calculate an authors' collaboration network:

```
# NetMatrix <- biblioNetwork(M, analysis = "collaboration", network = "authors", sep = ";")
```

or a country collaboration network:

```
# NetMatrix <- biblioNetwork(M, analysis = "collaboration", network = "countries", sep = ";")
```

Descriptive analysis of network graph characteristics

The function *networkStat* calculates several summary statistics.

In particular, starting from a bibliographic matrix (or an *igraph* object), two groups of descriptive measures are computed:

- The summary statistics of the network;
- The main indices of centrality and prestige of vertices.

```
# An example of a classical keyword co-occurrences network

NetMatrix <- biblioNetwork(M, analysis = "co-occurrences", network = "keywords", sep = ";")
netstat <- networkStat(NetMatrix)
```

The summary statistics of the network

This group of statistics allows to describe the structural properties of a network:

- **Size** is the number of vertices composing the network;
- **Density** is the proportion of present edges from all possible edges in the network;
- **Transitivity** is the ratio of triangles to connected triples;
- **Diameter** is the longest geodesic distance (length of the shortest path between two nodes) in the network;
- **Degree distribution** is the cumulative distribution of vertex degrees;
- **Degree centralization** is the normalized degree of the overall network;
- **Closeness centralization** is the normalized inverse of the vertex average geodesic distance to others in the network;
- **Eigenvector centralization** is the first eigenvector of the graph matrix;
- **Betweenness centralization** is the normalized number of geodesics that pass through the vertex;
- **Average path length** is the mean of the shortest distance between each pair of vertices in the network.

```
names(netstat$network)
```

```
##  [1] "networkSize"             "networkDensity"          "networkTransitivity"    
"networkDiameter"        
##  [5] "networkDegreeDist"       "networkCentrDegree"      "networkCentrCloseness"  
"networkCentrEigen"      
##  [9] "networkCentrbetweenness" "NetworkAverPathLeng"
```

The main indices of centrality and prestige of vertices

These measures help to identify the most important vertices in a network and the propensity of two vertices that are connected to be both connected to a third vertex.

The statistics, at vertex level, returned by *networkStat* are:

- **Degree centrality**
- **Closeness centrality** measures how many steps are required to access every other vertex from a given vertex;
- **Eigenvector centrality** is a measure of being well-connected connected to the well-connected;
- **Betweenness centrality** measures brokerage or gatekeeping potential. It is (approximately) the number of shortest paths between vertices that pass through a particular vertex;
- **PageRank score** approximates probability that any message will arrive to a particular vertex. This algorithm was developed by Google founders, and originally applied to website links;
- **Hub Score** estimates the value of the links outgoing from the vertex. It was initially applied to the web pages;
- **Authority Score** is another measure of centrality initially applied to the Web. A vertex has high authority when it is linked by many other vertices that are linking many other vertices;
- **Vertex Ranking** is an overall vertex ranking obtained as a linear weighted combination of the centrality and prestige vertex measures. The weights are proportional to the loadings of the first component of the Principal Component Analysis.

```
names(netstat$vertex)
```

```
## NULL
```

To summarize the main results of the *networkStat* function, use the generic function *summary*. It displays the main information about the network and vertex description through several tables.

summary accepts one additional argument. *k* is a formatting value that indicates the number of rows of each table. Choosing k=10, you decide to see the first 10 vertices.

```
summary(netstat, k=10)
```

```
##
##
## Main statistics about the network
##
##  Size                                  466
##  Density                               0.023
##  Transitivity                          0.324
##  Diameter                              5
##  Degree Centralization                 0.304
##  Average path length                   2.743
##
```

Visualizing bibliographic networks

All bibliographic networks can be graphically visualized or modeled.

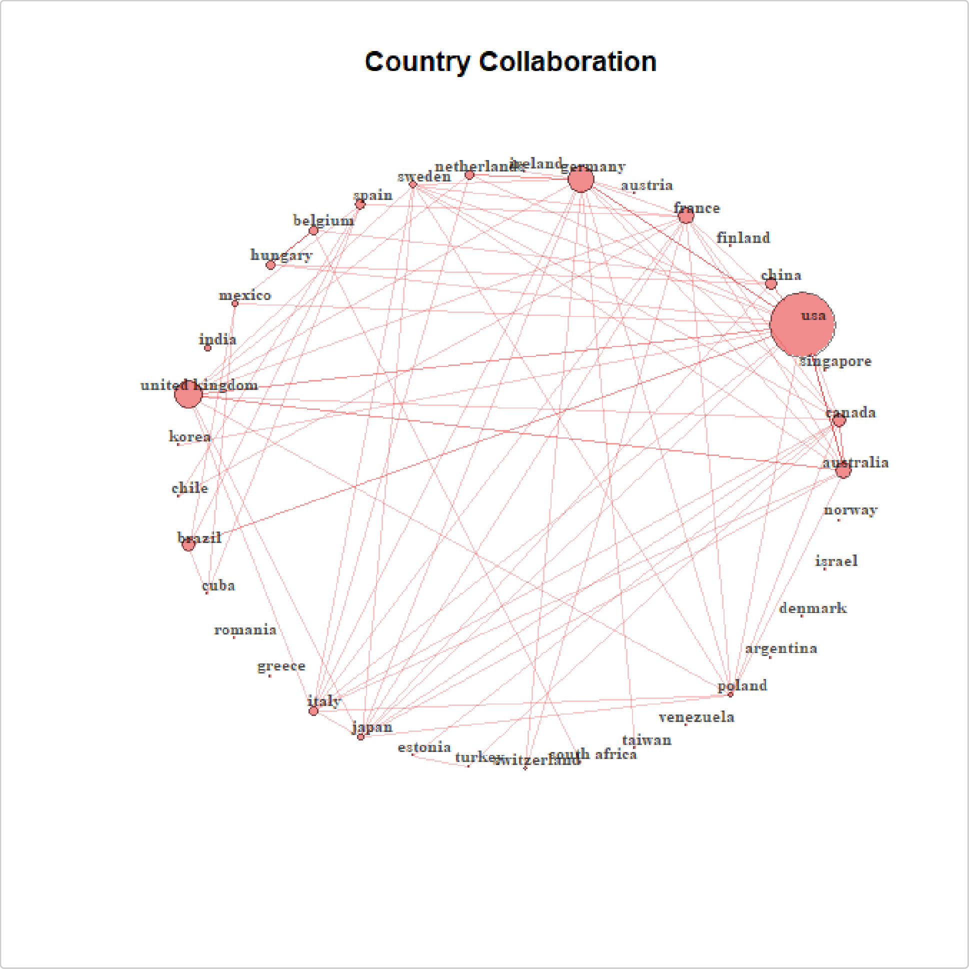
Here, we show how to visualize networks using function *networkPlot* and *VOSviewer software* by Nees Jan van Eck and Ludo Waltman (http://www.vosviewer.com).

Using the function *networkPlot*, you can plot a network created by *biblioNetwork* using R routines or using *VOSviewer*.

The main argument of *networkPlot* is type. It indicates the network map layout: circle, kamada-kawai, mds, etc. Choosing type="vosviewer", the function automatically: (i) saves the network into a pajek network file, named "vosnetwork.net"; (ii) starts an instance of VOSviewer which will map the file "vosnetwork.net". You need to declare, using argument *vos.path*, the full path of the folder where VOSviewer software is located (es. vos.path='c:/software/VOSviewer').

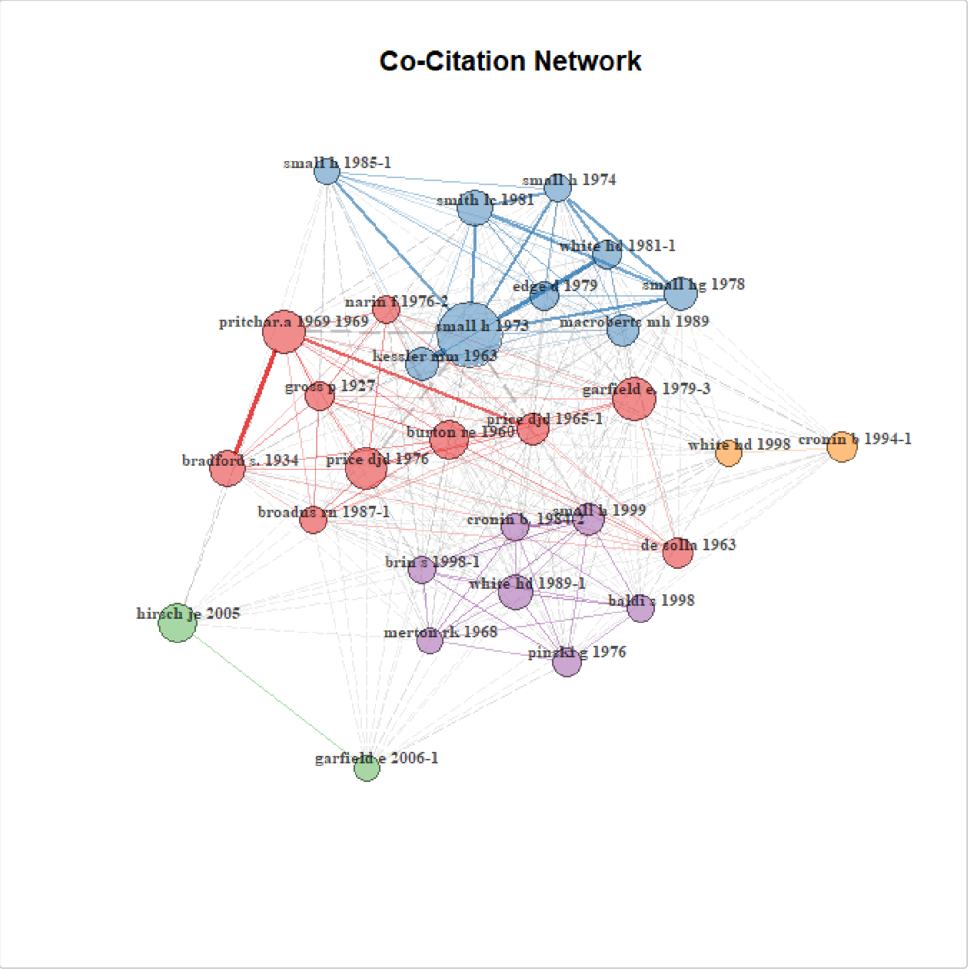
Country Scientific Collaboration

```
# Create a country collaboration network

M <- metaTagExtraction(M, Field = "AU_CO", sep = ";")
NetMatrix <- biblioNetwork(M, analysis = "collaboration", network = "countries", sep = ";")

# Plot the network
net=networkPlot(NetMatrix, n = dim(NetMatrix)[1], Title = "Country Collaboration", type =
  "circle", size=TRUE, remove.multiple=FALSE,labelsize=0.7,cluster="none")
```



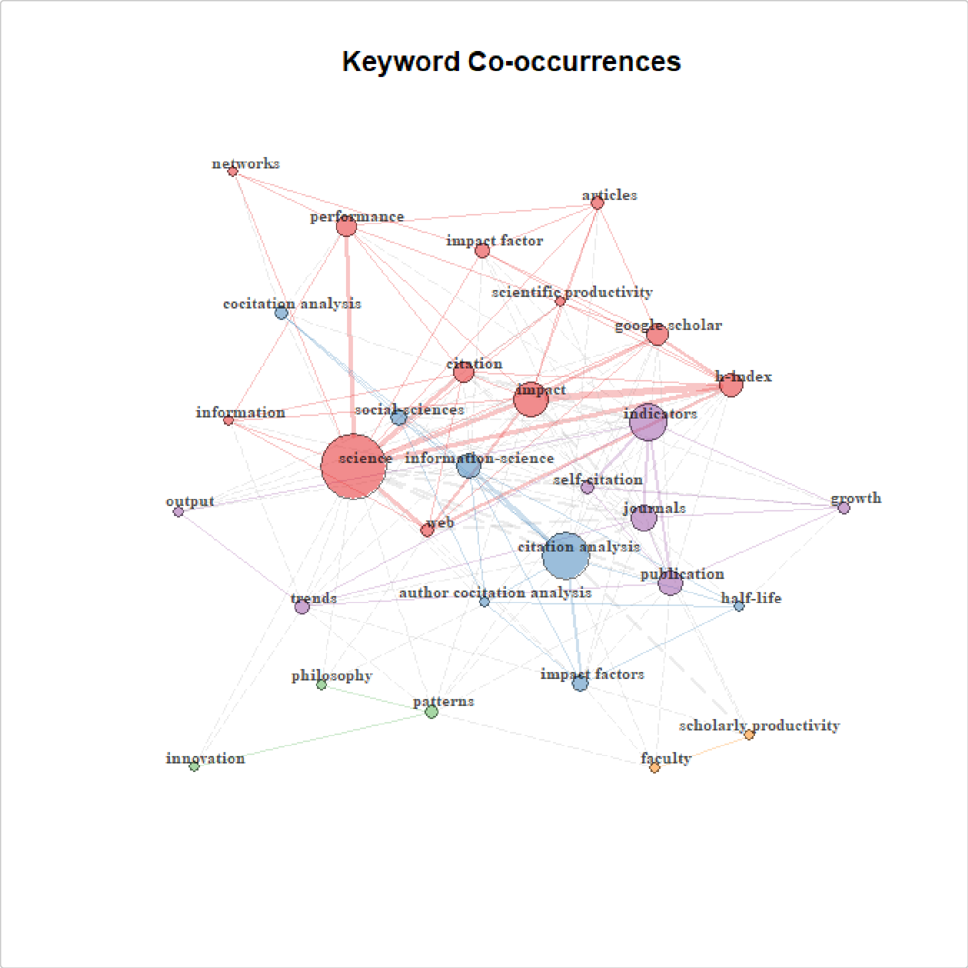
Co-Citation Network

```
# Create a co-citation network

NetMatrix <- biblioNetwork(M, analysis = "co-citation", network = "references", sep = ";")

# Plot the network
net=networkPlot(NetMatrix, n = 30, Title = "Co-Citation Network", type = "fruchterman",
  size=T, remove.multiple=FALSE, labelsize=0.7,edgesize = 5)
```



Keyword co-occurrences

```
# Create keyword co-occurrences network

NetMatrix <- biblioNetwork(M, analysis = "co-occurrences", network = "keywords", sep = ";")

# Plot the network
net=networkPlot(NetMatrix, normalize="association", weighted=T, n = 30, Title = "Keyword Co-
  occurrences", type = "fruchterman", size=T,edgesize = 5,labelsize=0.7)
```



Co-Word Analysis: The conceptual structure of a field

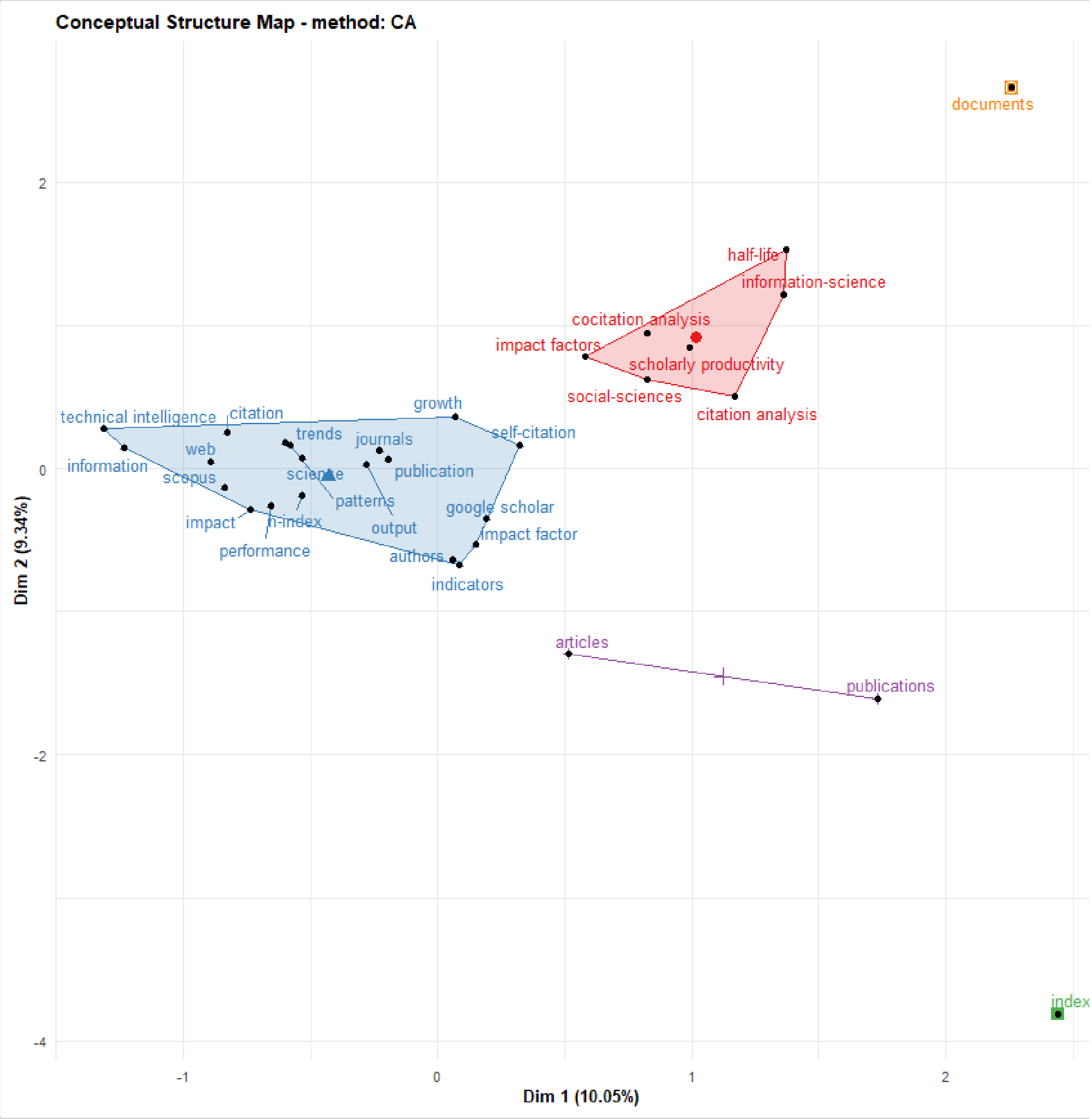
The aim of the co-word analysis is to map the conceptual structure of a framework using the word co-occurrences in a bibliographic collection.

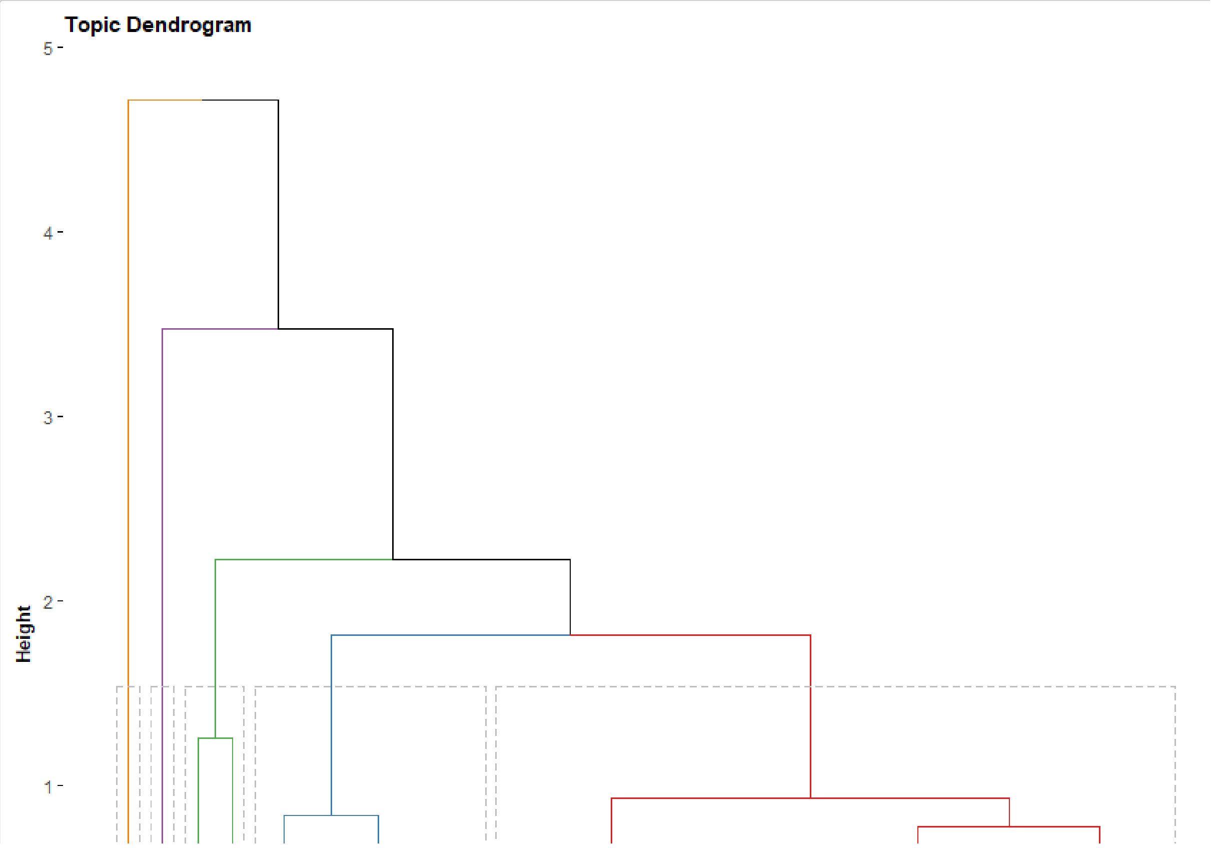
The analysis can be performed through dimensionality reduction techniques such as Multidimensional Scaling (MDS), Correspondence Analysis (CA) or Multiple Correspondence Analysis (MCA).

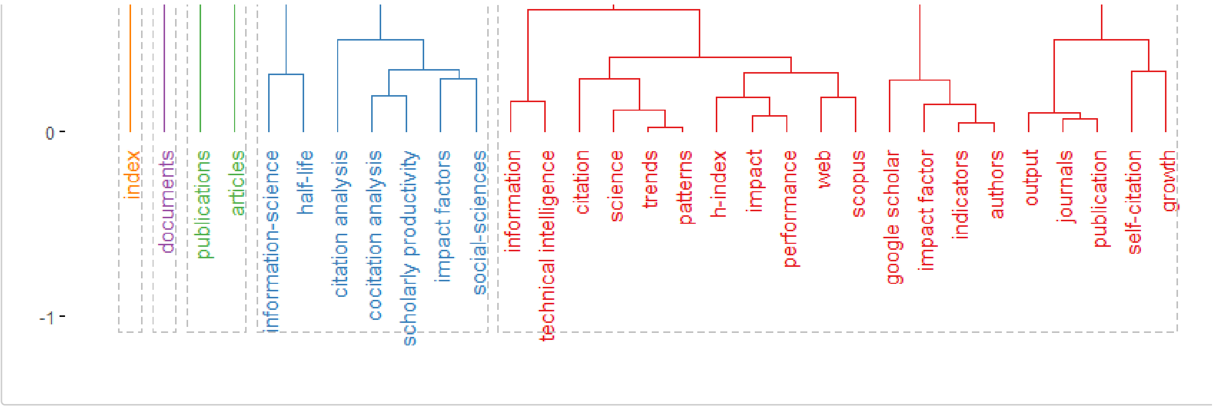
Here, we show an example using the function *conceptualStructure* that performs a CA or MCA to draw a conceptual structure of the field and K-means clustering to identify clusters of documents which express common concepts. Results are plotted on a two-dimensional map.

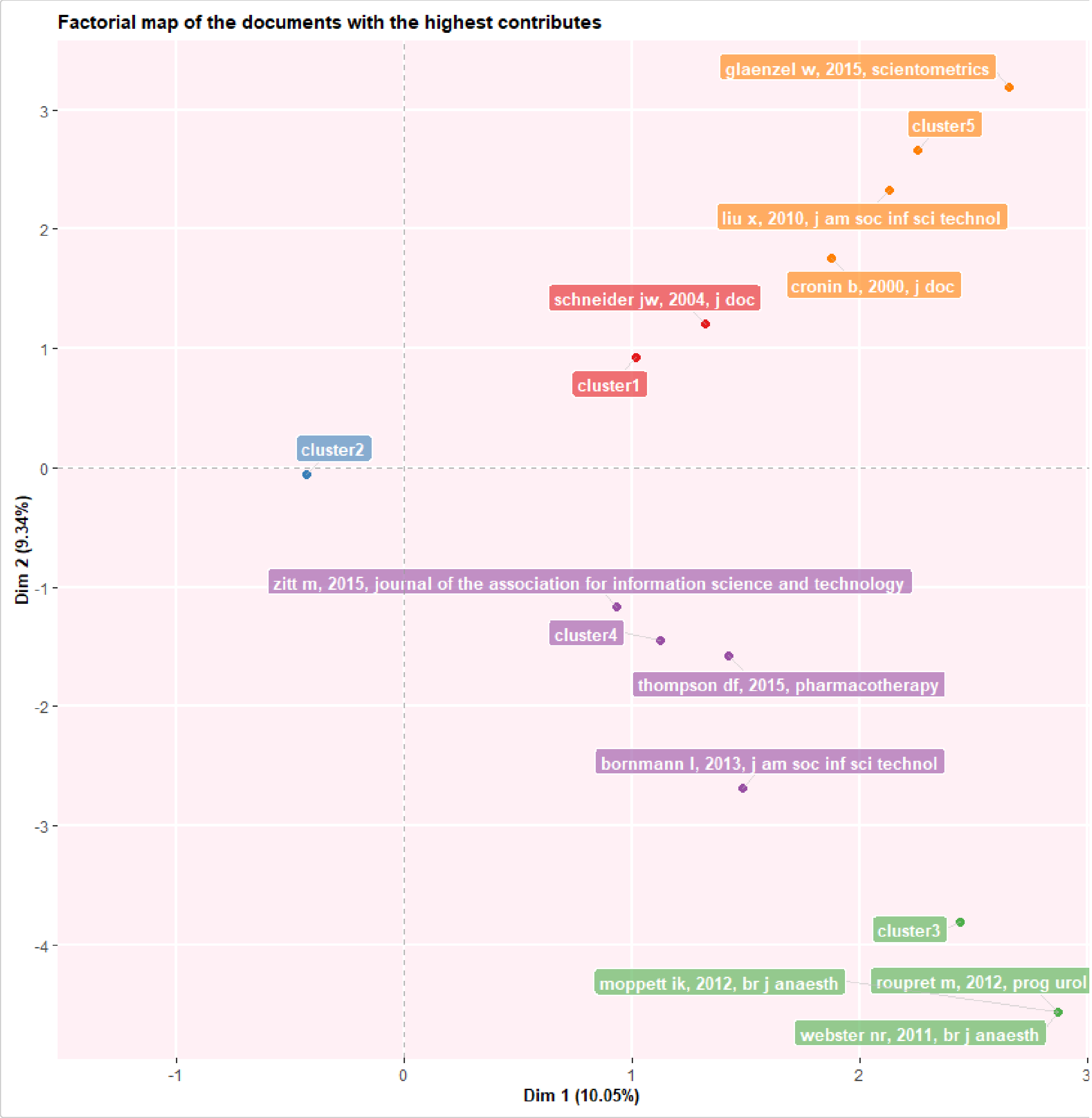
conceptualStructure includes natural language processing (NLP) routines (see the function *termExtraction*) to extract terms from titles and abstracts. In addition, it implements the Porter’s stemming algorithm to reduce inflected (or sometimes derived) words to their word stem, base or root form.

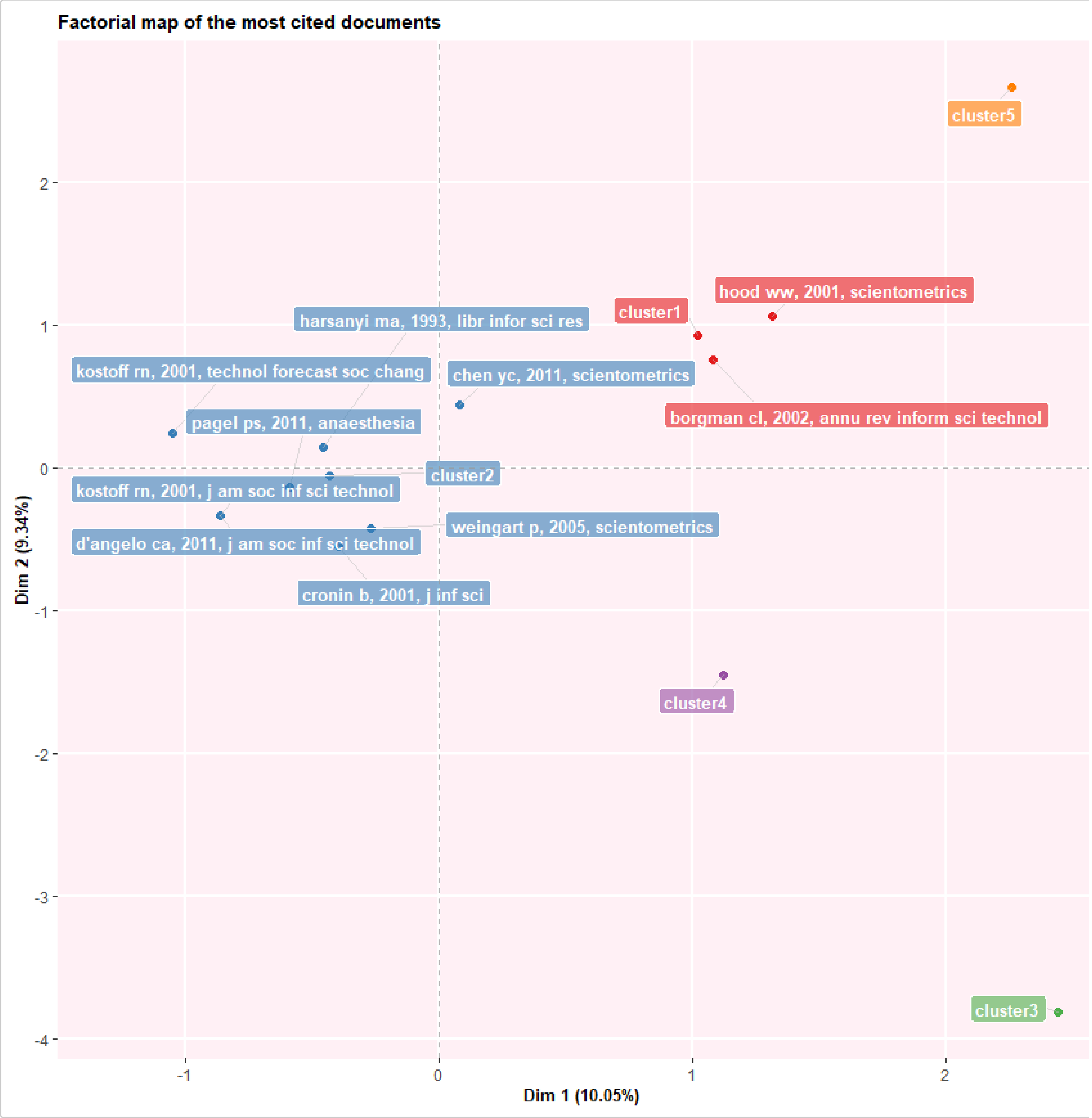
```
# Conceptual Structure using keywords (method="CA")

CS <- conceptualStructure(M,field="ID", method="CA", minDegree=4, clust=5, stemming=FALSE,
  labelsize=10, documents=10)
```


Conceptual Structure Map - method: CA
Dim 1 (10.05%)
Dim 2 (9.34%)
-1
0
1
2
-4
-2
documents
half-life
information-science
cocitation analysis
impact factors
scholarly productivity
social-sciences
citation analysis
technical intelligence
citation
growth
trends
journals
self-citation
web
information
scopus
science
publication
patterns
google scholar
impact
h-index
output
impact factor
performance
authors
indicators
articles
publications
index


Topic Dendrogram
Height
1
2
3
4
5


0
-1
index
documents
publications
articles
information-science
half-life
citation analysis
cocitation analysis
scholarly productivity
impact factors
social-sciences
information
technical intelligence
citation
science
trends
patterns
h-index
impact
performance
web
scopus
google scholar
impact factor
indicators
authors
output
journals
publication
self-citation
growth


Factorial map of the documents with the highest contributes
glaenzel w, 2015, scientometrics
cluster5
liu x, 2010, j am soc inf sci technol
cronin b, 2000, j doc
schneider jw, 2004, j doc
cluster1
cluster2
zitt m, 2015, journal of the association for information science and technology
cluster4
thompson df, 2015, pharmacotherapy
bornmann l, 2013, j am soc inf sci technol
cluster3
moppett ik, 2012, br j anaesth
roupret m, 2012, prog urol
webster nr, 2011, br j anaesth
Dim 2 (9.34%)
3
2
1
0
-1
-2
-3
-4
-1
0
1
2
3
Dim 1 (10.05%)



Historical Direct Citation Network

The historiographic map is a graph proposed by E. Garfield (2004) to represent a chronological network map of most relevant direct citations resulting from a bibliographic collection.

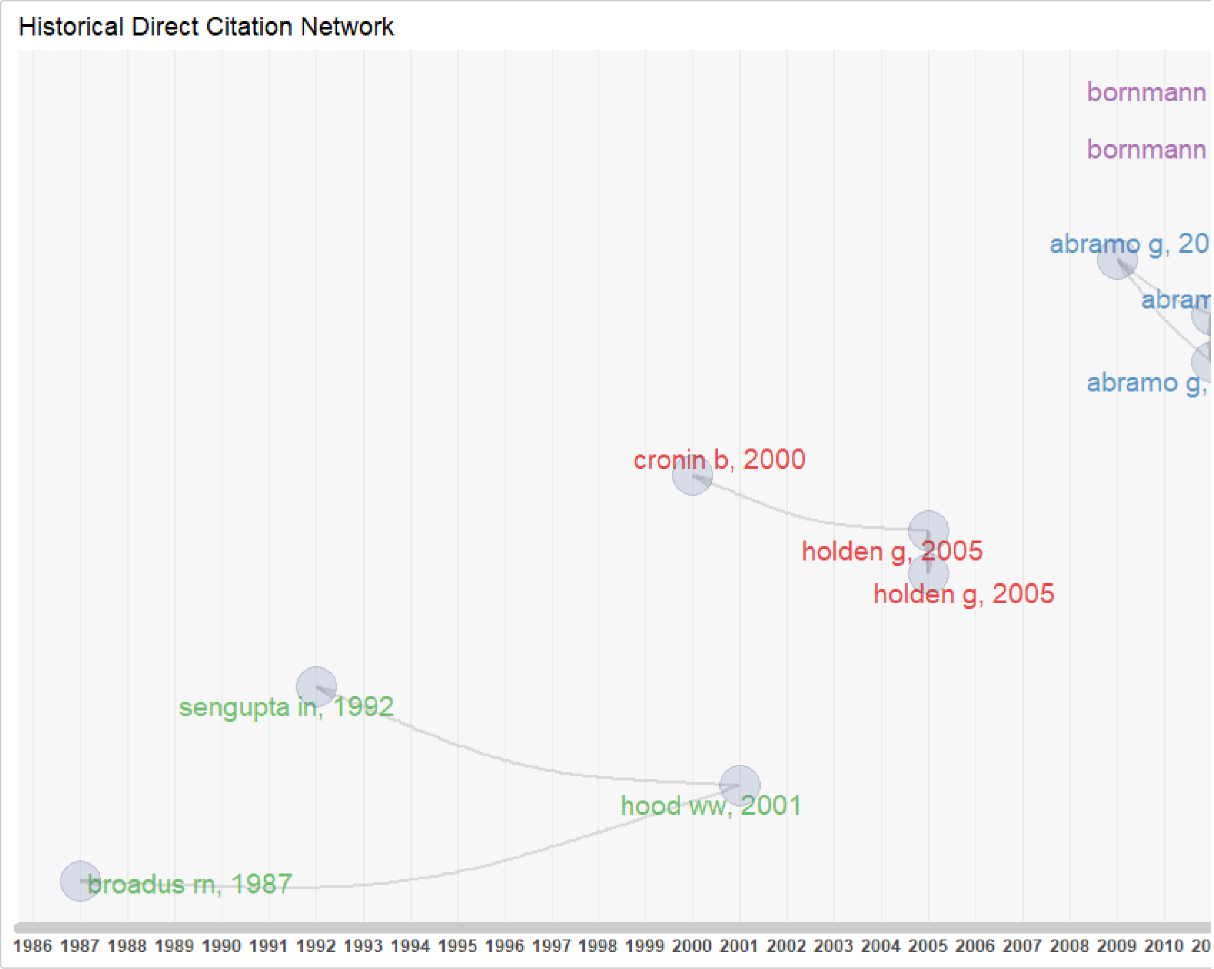
Garfield, E. (2004). Historiographic mapping of knowledge domains literature. Journal of Information Science, 30(2), 119-145.

The function generates a chronological direct citation network matrix which can be plotted using *histPlot*:

```
# Create a historical citation network
options(width=130)
histResults <- histNetwork(M, min.citations = 10, sep = ";")
```

```
## Articles analysed   84
```

```
# Plot a historical co-citation network
net <- histPlot(histResults, n=15, size = 10, labelsize=5)
```



```
##
##  Legend
##
##                                            Paper                              DOI Year LCS
GCS
## 1986 - 2         PERSSON O, 1986, SCIENTOMETRICS               10.1007/BF02016861 1986   3
15
## 1987 - 3        BROADUS RN, 1987, SCIENTOMETRICS               10.1007/BF02016680 1987   5
38
## 1989 - 6            BORGMAN CL, 1989, COMMUN RES       10.1177/009365089016005002 1989   3
28
## 1992 - 13         GARG KC, 1992, J SCI IND RES-a                             <NA> 1992   2
14
## 1992 - 14               SENGUPTA IN, 1992, LIBRI        10.1515/LIBR.1992.42.2.75 1992   4
20
## 1992 - 25                  CRONIN B, 2000, J DOC         10.1108/EUM0000000007123 2000   4
20
## 2001 - 29          HOOD WW, 2001, SCIENTOMETRICS          10.1023/A:1017919924342 2001   2
71
## 2005 - 41               KOSTOFF RN, 2005, ENERGY     10.1016/J.ENERGY.2004.04.058 2005   2
39
## 2005 - 43   HOLDEN G, 2005, SOC WORK HEALTH CARE           10.1300/J010V41N03\\_01 2005   6
22
## 2005 - 44 HOLDEN G, 2005, SOC WORK HEALTH CARE-a           10.1300/J010V41N03\\_03 2005   6
34
## 2006 - 48        GLANZEL W, 2006, SCIENTOMETRICS       10.1556/SCIENT.67.2006.2.8 2006   3
41
## 2008 - 52            THELWALL M, 2008, J INF SCI         10.1177/0165551507087238 2008   2
32
## 2008 - 54     SMITH DR, 2008, CONTACT DERMATITIS 10.1111/J.1600-0536.2008.01405.X 2008   4
11
## 2009 - 61             ABRAMO G, 2009, RES POLICY     10.1016/J.RESPOL.2008.11.001 2009   4
43
## 2011 - 68         ABRAMO G, 2011, SCIENTOMETRICS        10.1007/S11192-011-0459-X 2011   4
16
## 2011 - 72       ABRAMO G, 2011, SCIENTOMETRICS-a        10.1007/S11192-011-0352-7 2011   4
35
## 2013 - 82          BORNMANN L, 2013, J INFORMETR        10.1016/J.JOI.2013.02.005 2013   5
10
```

```
## 2013 - 83        BORNMANN L, 2013, J INFORMETR-a        10.1016/J.JOI.2012.09.003 2013   5
11
```

Main Authors' references (about bibliometrics)

Aria, M. & Cuccurullo, C. (2017). *bibliometrix*: An R-tool for comprehensive science mapping analysis, *Journal of Informetrics*, 11(4), pp 959-975, Elsevier, DOI: 10.1016/j.joi.2017.08.007 (https://doi.org/10.1016/j.joi.2017.08.007).

Cuccurullo, C., Aria, M., & Sarto, F. (2016). Foundations and trends in performance management. A twenty-five years bibliometric analysis in business and public administration domains, *Scientometrics*, DOI: 10.1007/s11192-016-1948-8 (https://doi.org/10.1007/s11192-016-1948-8).

Cuccurullo, C., Aria, M., & Sarto, F. (2015). Twenty years of research on performance management in business and public administration domains. Presentation at the *Correspondence Analysis and Related Methods conference (CARME 2015)* in September 2015 (http://www.bibliometrix.org/documents/2015Carme_cuccurulloetal.pdf).

Sarto, F., Cuccurullo, C., & Aria, M. (2014). Exploring healthcare governance literature: systematic review and paths for future research. *Mecosan* (http://www.francoangeli.it/Riviste/Scheda_Rivista.aspx?IDarticolo=52780&lingua=en).

Cuccurullo, C., Aria, M., & Sarto, F. (2013). Twenty years of research on performance management in business and public administration domains. In *Academy of Management Proceedings* (Vol. 2013, No. 1, p. 14270). Academy of Management (https://doi.org/10.5465/AMBPP.2013.14270abstract).