

R tools for accessing research literature for text mining

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Abstract

Text mining is a powerful method for answering research questions. However, getting texts to extract information can be a daunting and complicated task. The primary reason for this is the diversity of publisher technologies. There are thousands of different publishers, each with their own licenses, URL patterns, access options, and more. Layered on top of that is the varied access each user has based on their institutional affiliation. Here, I introduce a suite of software packages in the R programming language for fetching texts. The tapestry of different publishers, access levels, and other factors requires a patchwork of approaches for getting texts to users. The flagship R package called `fulltext` attempts to simplify search and retrieval of texts for text mining by serving as an interface to the varied and complex publishers. The `fulltext` package, along with many others, make acquiring texts easier than ever, facilitating answering research questions with text mining.

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5 Introduction

There's more than 100 million research articles published (Crossref API: <https://github.com/CrossRef/rest-api-doc>), representing an enormous amount of knowledge. In addition to simply reading these articles, the articles contain a vast trove of information of interest to researchers for machine aided questions (Kong & Gerstein, 2018; Usai et al., 2018). For example, many researchers are interested in statistical outcomes of articles that can be extracted from numeric results: P-values, effect sizes, means, and more. In addition, researchers are often interested in words in articles, their use through time, and the contexts they are found in.

Text mining is the broad term associated with pulling information out of articles. Given the importance of text mining, good text mining tools are needed to make it easier for researchers to do. Graphical user interface (GUI) based text mining tools are available (e.g., Ba & Bossy, 2016; Cañada et al., 2017; Muñoz, Kissling & Loon, 2019) and some research papers have used them (Chaix et al., 2019), but given the urgent recent call to action for more reproducible research (Open Science Collaboration, 2015; Camerer et al., 2016, 2018), we must move away from GUI based tools as fast as possible. A number of examples of programmatic tools can be found in the literature. For example, Sinclair et al. (2016) present a tool in Python called seqenv for the domain specific task of linking sequences to environments through text mining.

Using programmatic tools for text mining is important for a variety of reasons. First, using programmatic tools makes it easier for yourself. You can re-run code to get updated results as data changes, and results can always be re-created. Second, code can be shared whereas GUI driving workflows can not; colleagues, reviewers and other researchers can reproduce and check your work. (FIXME: re-work this; citations)

Most recent text mining papers do not use programmatic approaches, highlighting the need for more programmatic text mining tools, and increased discussion of those tools to increase awareness. For example, many papers search Web of Science using their web interface, and downloading papers manually (Ding, Li & Fan, 2018; McCallen et al., 2019). Many of these papers doing GUI based searching and paper downloads are using R or Python downstream for analysis; replacing GUI based data acquisition with programmatic approaches will improve research.

The R programming language is free of cost, and is used widely throughout many academic fields; tools in R for text mining are of particular importance because they can be adopted by academics rapidly.

35 Here, I present an overview of text mining tools in the R programming language, not for text mining
36 analysis, but rather those tools for searching for, acquiring, and extracting parts of texts (e.g., title,
37 abstract, authors). Most of the packages presented here are part of the rOpenSci suite ([https://ropensci.
38 org/](https://ropensci.org/)).

39 **Digital articles: technical aspects**

40 Those articles that are digital (which in theory includes all articles) can be split into two groups:
41 machine readable and non-machine readable.

42 The machine readable articles are those in XML¹, JSON², or plain text format. The former two, XML
43 and JSON, are the best machine readable types because they are structured data³, whereas plain text
44 has no structure - it's simply a set of characters with line breaks and spaces in between.

45 Of the non-machine readable types, the most notable is the Portable Document Format (PDF)⁴. These
46 can be broken out into two groups: text based PDFs and scanned PDFs (images of text). The former
47 are converted from digital versions of various kinds (MS Word, OpenOffice, LaTeX, markdown, etc.),
48 while the latter are created by scanning print articles to a PDF format. Text-based PDFs are much
49 better for text mining purposes as plain text can be extracted easily in R with [pdftools](#), a binding to
50 [libpoppler](#). However, with scanned PDFs, text must be extracted using Optimal Character Recognition
51 (OCR; see R package [tesseract](#)), which isn't always a clean solution, especially compared to true text
52 based PDFs.

53 The reality in scholarly publishing is all publishers, if they provide any access to their articles, only
54 provide PDF format. Very few publishers, with some quite large (Elsevier, Pensoft, PLOS), provide
55 XML format. Although most publishers most likely have the XML behind each of their articles, they for
56 some indefensible reason do not share it - making text mining more difficult. Some provide plain text
57 (Elsevier). I only know of one publisher that provides full text as JSON (PLOS). Thus, text mining, in
58 most cases, will require extracting text from PDFs.

¹<https://www.w3.org/TR/xml/>

²<https://tools.ietf.org/html/rfc7159>

³https://en.wikipedia.org/wiki/Data_model

⁴<https://en.wikipedia.org/wiki/PDF>

59 **Digital articles: the access landscape**

60 Acces to full-text is the holy grail in text mining. Some use cases can get by with article metadata
61 (authors, title, etc.), some with abstracts, but many use cases require full-text.

62 The landscape of access to full-text is extremely hetergeous, with the majority of variation along the
63 publisher axis. The major hurdle is paywalls. The majority of articles are published by the big three
64 publishers - Wiley, Springer, Elsevier - and the majority of their articles are behind paywalls.

65 A promising sign is an increasing number of open access articles, yet open access articles represent a
66 small percent of all articles: an estimate in 2018 said that 28% of the scholarly literature was open
67 access (Piwowar et al., 2018).

68 With respect to paywalled articles, access varies by institution, depending on each institution's publisher
69 contracts. MORE ABOUT THIS ...

70 Some may not realize access to articles varies with IP address so that access from campus vs. from
71 home (if not on a VPN) will drastically differ. Sometimes a VPN is required, and this can provide a
72 significant technical hurdle to users attempting to do text mining work.

73 One final hurdle in text mining comes unsurprisingly from Elsevier. They use so-called "fences" for
74 programmatic access. That is, even if a person trying to get an article programmatically their institution
75 has access to and they have access to, and they are on the correct IP address, they may still not get
76 access to an Elsevier article. Elsevier puts in place these fences and only if you contact their technical
77 team directly can you get these fences removed, and only then on a per institution basis.

78 I can not end this section without mentioning SciHub. This is a last resort option for many probably
79 (or possibly first, depending on your level of access), providing access to full text of articles that are
80 normally paywalled. No tools in this manuscript provide access to SciHub.

81 **The discovery problem**

82 A text mining project starts with a question. From that question, researchers then attempt to acquire
83 scholarly articles for text mining. Finding appropriate articles is not altogether straight-forward.

84 Some of the discovery difficulty relates to the fact that there are so many places to search for articles;
85 a non-exhaustive list: Google Scholar, Microsoft Academic Research, Scopus, ScienceDirect, Web of

86 Science, Pubmed/Entrez, Europe PMC, Directory of Open Access Journals, Open Knowledge Maps,
87 CORE, Fatcat, and more. It's probably difficult to know where the best place is to search. Some of
88 these are paywalled (e.g., Web of Science), and some are not.

89 The most important aspect about any source for article search with respect to reproducible research is
90 being able to use the data source programmatically. Of those listed above, the following can be used
91 programmatically: Microsoft Academic Research, Scopus, ScienceDirect, Pubmed/Entrez, Europe PMC,
92 and Directory of Open Access Journals. All of these are included in the R package [fulltext](#), discussed
93 further below.

94 On top of the vast array of different data sources is the varied ways that search is implemented in each
95 source. Most sources are probably using Solr or Elasticsearch under the hood, though we can't know
96 this for sure as most do not make their software infrastructure public knowledge. Nonetheless, data
97 sources differ in how search works from the user perspective. For example, some provide wild card/fuzzy
98 search (i.e., 'appl*' includes results for 'apple', 'application', etc.) and some do not. Some sources
99 are searching full text of articles, while others only search metadata (i.e., title, authors, abstract). In
100 addition, each source has a different set of metadata/full text available. In brief, the same search against
101 different sources produces different results. Some text mining research articles perform the same search
102 against many different sources (refs), while others choose just one source.

103 **Text mining in R: Three case studies**

104 *Case study 1: Citation mining*

105 In this example, xxxx

106 *Load libraries*

```
library("rcrossref")  
library("rplos")  
library("rorcid")  
library("rcitoid")  
library("citecorp")
```

107 *rcrossref*

108 Using `rcrossref` for Crossref data:

```
x <- cr_works(query="NSF")
head(x$data)
#> # A tibble: 6 x 32
#>   alternative.id container.title created deposited published.print doi
#>   <chr>           <chr>           <chr>  <chr>      <chr>           <chr>
#> 1 S106352031630~ Applied and Co~ 2016-0~ 2019-02-~ 2018-03      10.1~
#> 2 <NA>           Biogeosciences~ 2017-0~ 2017-07-~ <NA>         10.5~
#> 3 <NA>           Global Biogeoc~ 2018-0~ 2019-01-~ 2018-10      10.1~
#> 4 <NA>           IEEE Communica~ 2016-1~ 2017-12-~ 2017         10.1~
#> 5 S002178241400~ Journal de Mat~ 2014-0~ 2018-10-~ 2014-10      10.1~
#> 6 123           Light: Science~ 2019-0~ 2019-01-~ 2019-12      10.1~
#> # ... with 26 more variables: indexed <chr>, issn <chr>, issue <chr>,
#> #   issued <chr>, member <chr>, page <chr>, prefix <chr>, publisher <chr>,
#> #   reference.count <chr>, score <chr>, ...
```

109 Case study 2: Abstract mining

110 Sometimes you just need abstracts for your research question. The benefit of only needing abstracts,
 111 and not need full text, is that there's many more articles that will have abstracts available than have
 112 their full text available.

113 As an example, let's say you xxxx

```
library("fulltext")
```

114 *xxxxx*

115 Using fulltext:

```
res <- ft_search("ecology", from = "crossref",
  crossrefopts = list(filter = c(has_abstract = TRUE)))
ids <- res$crossref$data$doi
out <- ft_abstract(x = ids, from = "crossref")
abstracts <- vapply(out$crossref, "[[", "", "abstract")
```

116 Using `quanteda`, read the abstracts into a corpus

```
library("quanteda")
corp <- corpus(abstracts)
docvars(corp) <- ids
```

117 Get a summary of the abstracts

```
summary(corp)
#> Corpus consisting of 10 documents:
#>
#>   Text Types Tokens Sentences          V1
#> text1    143    262         10 10.2458/v22i1.21112
#> text2    117    244          6 10.2458/v17i1.21696
#> text3     75    118          4 10.2458/v25i1.23119
#> text4      5      8          1 10.2458/v1i1.21154
#> text5    105    171          7 10.1155/2011/868426
#> text6    112    181          6 10.1155/2012/273413
#> text7    117    240          8 10.5194/we-13-91-2013
#> text8    140    245          9 10.5194/we-13-95-2013
#> text9    107    202          7 10.1155/2014/198707
#> text10   118    224          6 10.5402/2011/897578
#>
#> Source: /Users/sckott/github/ropensci/textmine/use-cases/* on x86_64 by sckott
#> Created: Thu Apr 11 11:20:19 2019
#> Notes:
```

118 Use the `kwic()` function to see a word in context across the abstracts

```
kwic(corp, pattern = "ecology")
#>
#> [text1, 33] knowledge production within critical political / ecology /
#> [text1, 50]                in scientific articles on dryland / ecology /
```

#> [text1, 204] to equilibrium models in range / ecology /

#> [text1, 246] communal areas.Keywords: Critical political / ecology /

#> [text1, 255] , scientific models, rangeland / ecology /

#> [text2, 5] < jats:p> Political / ecology /

#> [text2, 23] manifestations of political economy and / ecology /

#> [text2, 45] I try to extend political / ecology /

#> [text2, 149] , in dialogue with political / ecology /

#> [text2, 177] people and resources that political / ecology /

#> [text2, 229] indigeneity scholars.Key words: political / ecology /

#> [text3, 71] an analysis from a political / ecology /

#> [text3, 114] system, supermarkets, political / ecology /

#> [text6, 134] was observed when allopatry and / ecology /

#> [text7, 167] ecosystem should be considered for / ecology /

#> [text7, 185] the" four-color issue of / ecology /

#> [text7, 201] step toward advancing knowledge in / ecology /

#> [text9, 195] or for theoretical studies integrating / ecology /

#>

#> . This article is a

#> , and investigates the functions

#> , and the fence-line photographs

#> , fence-line photography, scientific

#> , Southern Africa</

#> has expanded in multiple new

#> in the" problem"

#> to engage with ethnic studies

#> approaches to better understand the

#> focuses on cannot be adequately

#> , coloniality, Maidu,

#> standpoint allows a different interpretation

#> </ jats:p>

#> act together, leading to


```
#> "? Here, I
#> ", and propose that
#> and conservation biology. In
#> and biogeography.</
```

119 *Case study 3: Full text mining*

120 In this example, xxxx

```
library("fulltext")
# library("crminer")
```

121 *Search for articles*

122 Search for the term *ecology* in PLOS journals.

```
(res1 <- ft_search(query = 'ecology', from = 'plos'))
#> Query:
#> [ecology]
#> Found:
#> [PLOS: 47272; BMC: 0; Crossref: 0; Entrez: 0; arxiv: 0; biorxiv: 0; Europe PMC: 0; Scopus: 0]
#> Returned:
#> [PLOS: 10; BMC: 0; Crossref: 0; Entrez: 0; arxiv: 0; biorxiv: 0; Europe PMC: 0; Scopus: 0; .
```

123 Each publisher/search-engine has a slot with metadata and data

```
res1$plos
#> Query: [ecology]
#> Records found, returned: [47272, 10]
#> License: [CC-BY]
#>
#> id
#> 1 10.1371/journal.pone.0001248
#> 2 10.1371/journal.pone.0059813
#> 3 10.1371/journal.pone.0080763
```

```
#> 4 10.1371/journal.pone.0155019
#> 5 10.1371/journal.pone.0175014
#> 6 10.1371/journal.pone.0150648
#> 7 10.1371/journal.pone.0208370
#> 8 10.1371/journal.pcbi.1003594
#> 9 10.1371/journal.pone.0102437
#> 10 10.1371/journal.pone.0166559
```

124 *Get full text*

125 Using the results from `ft_search()` we can grab full text of some articles

```
(out <- ft_get(res1))
#> <fulltext text>
#> [Docs] 10
#> [Source] ext - /Users/sckott/Library/Caches/R/fulltext
#> [IDs] 10.1371/journal.pone.0001248 10.1371/journal.pone.0059813
#>      10.1371/journal.pone.0080763 10.1371/journal.pone.0155019
#>      10.1371/journal.pone.0175014 10.1371/journal.pone.0150648
#>      10.1371/journal.pone.0208370 10.1371/journal.pcbi.1003594
#>      10.1371/journal.pone.0102437 10.1371/journal.pone.0166559 ...
```

126 *Extract text from pdfs*

127 Ideally for text mining you have access to XML or other text based formats. However, sometimes you
 128 only have access to PDFs. In this case you want to extract text from PDFs. `fulltext` can help with
 129 that.

130 You can extract from any pdf from a file path, like:

```
path <- system.file("examples", "example1.pdf", package = "fulltext")
ft_extract(path)
#> <document>/Library/Frameworks/R.framework/Versions/3.5/Resources/library/fulltext/examples/ex
#> Title: Suffering and mental health among older people living in nursing homes---a mixed-met
```

```
#> Producer: pdfTeX-1.40.10
#> Creation date: 2015-07-17
```

131 *Extract text chunks*

132 Requires the [pubchunks](#) library. Here, we'll search for some PLOS articles, then get their full text, then
 133 extract various parts of each article with `pub_chunks()`.

```
library("pubchunks")
res <- ft_search(query = "ecology", from = "plos", limit = 3)
x <- ft_get(res)
x %>% ft_collect() %>% pub_chunks(c("doi", "history")) %>% pub_tabularize()

#> $plos
#> $plos$`10.1371/journal.pone.0001248`
#>
#> doi history.received history.accepted
#> 1 10.1371/journal.pone.0001248      2007-07-02      2007-11-06
#> .publisher
#> 1      plos
#>
#> $plos$`10.1371/journal.pone.0059813`
#>
#> doi history.received history.accepted
#> 1 10.1371/journal.pone.0059813      2012-09-16      2013-02-19
#> .publisher
#> 1      plos
#>
#> $plos$`10.1371/journal.pone.0080763`
#>
#> doi history.received history.accepted
#> 1 10.1371/journal.pone.0080763      2013-08-15      2013-10-16
#> .publisher
#> 1      plos
```

134 **Data sources**

135 There is increasing open access scientific literature content available online. However, only a small
136 proportion of scientific journals provide access to their full text; whereas, most publishers provide open
137 access to their metadata only (most often through Crossref; Table 1). The following is a synopsis of the
138 major data sources and associated R tools.

Table 1. Sources of scientific literature, their content type provided via web services, whether rOpenSci has an R packages for the service, and where to find the API documentation.

| Data Provider | Content Type | rOpenSci Package | Documentation |
|-----------------------------------|------------------------------|-------------------|--------------------|
| Crossref | Metadata | rcrossref/crminer | 5 |
| DataCite | Metadata | rdatacite | 6 |
| Biodiversity Heritage Library | Full text/Metadata | rbhl | 7 |
| Public Library of Science (PLOS) | Full text (pdf/xml)/Metadata | rplos | 8 |
| Scopus (Elsevier) | Full text (pdf/xml)/Metadata | fulltext | 9 |
| arXiv | Full text (pdf)/Metadata | aRxiv | 10 |
| Biomed Central (via Springer) | Full text (pdf)/Metadata | fulltext | 11 |
| bioRxiv | Full text (pdf)/Metadata | fulltext | 12 |
| PMC/Pubmed (via Entrez) | Full text (pdf/xml)/Metadata | rentrez | 13 |
| Europe PMC | Full text (pdf/xml)/Metadata | europemc | 14 |
| Microsoft Academic Search | Metadata | microdemic | 15 |
| Directory of Open Access Journals | Metadata | jaod | 16 |
| JSTOR Data for Research | Full text | jstor | 17 |
| ORCID | Metadata | rorcid | 18 |
| Wikimedia's Citoid | Citations | rcitoid | 19 |
| Open Citation Corpus | Citations | citecorp | 20 |

⁵<https://api.crossref.org>

⁶<https://support.datacite.org/docs/api>

⁷<http://bit.ly/KYQ1Rd>

⁸<http://api.plos.org/solr>

⁹<http://bit.ly/J9S616>

¹⁰<https://arxiv.org/help/api/index>

¹¹<https://dev.springer.com/>

¹²<http://www.biorxiv.org/>

¹³<https://www.ncbi.nlm.nih.gov/books/NBK25500>

¹⁴<https://azure.microsoft.com/en-us/services/cognitive-services>

¹⁵<https://dev.labs.cognitive.microsoft.com/docs/services/56332331778daf02acc0a50b/operations/>

¹⁶[565d9001ca73072048922d97](https://doi.org/10.2196/2014.01.001)

¹⁷<https://doaj.org/api/v1/docs>

¹⁸<https://www.jstor.org/df/>

¹⁹<https://pub.orcid.org/>

²⁰https://en.wikipedia.org/api/rest_v1/#/Citation/getCitation

²¹<http://opencitations.net/>

| Data Provider | Content Type | rOpenSci Package | Documentation |
|---------------|--------------------------|------------------|--------------------|
| Fatcat | Metadata | none | 21 |
| SHERPA/RoMEO | Journal Level Metadata | rromeo | 22 |
| CORE | Full text (pdf)/Metadata | rcoreoa | 23 |
| Dissemin | Metadata | dissemr | 24 |

Crossref and Datacite

Crossref is a non-profit that creates (or “mints”) Digital Object Identifiers (DOIs). In addition, they maintain metadata associated with each DOI. The metadata ranges from simple (including author, title, dates, DOI, type, publisher) to including number of citations to the article, as well as references in the article, and even abstracts. At the time of writing they hold 100 million DOIs.

One can search by DOI or search citation data to get citations. In addition, Crossref has a text mining opt-in program for publishers. The result of this is that some publishers provide URLs for full text content of their articles. The majority of these links are pay-walled, while some are open access. Using any of the various tools for working with Crossref data, you can filter your search to get only articles with full text links, and further to get only articles with full text links that are open access.

The main interfaces for Crossref in R are [rcrossref](#) and [crminer](#). [rcrossref](#) is a complete client for the public facing Crossref web services including metadata, whereas [crminer](#) focuses only on retrieving full text of articles. Similar interfaces to [rcrossref](#) are available in Ruby ([serrano](#)) and Python ([habanero](#)).

Datacite is similar to Crossref, but focuses on datasets instead of articles. The main interface for Datacite in R is [rdatacite](#).

Biodiversity Heritage Library

The Biodiversity Heritage Library (BHL) houses scans of biodiversity books, and provides web interfaces and APIs to query and fetch those data. They also provide text of the scanned pages. The main R interace to BHL is through [rbhl](#).

²¹<https://fatcat.wiki/>

²²<https://www.sherpa.ac.uk/romeo/apimanual.php?la=en&flDnum=%7C&mode=simple>

²³<https://core.ac.uk/>

²⁴<https://dissemin.readthedocs.io/en/latest/api.html>

160 *Public Library of Science*

161 The Public Library of Science (PLOS) is one of the largest open access only publishers. They as of this
162 writing have published 2.1 million articles. One of the strong advantages of PLOS is that they provide
163 an API to their Solr instance, which is a very flexible way to search their articles. The main R interface
164 to PLOS is through [rplos](#).

165 *Elsevier/Scopus*

166 Elsevier is one of the largest publishers. Scopus is one of their products, a searchable database of
167 articles. Most of their articles are not open access. However, they have a number of advantages if you
168 have access to their articles: they are one of the few publishers to provide machine readable XML (many
169 publishers do have XML versions of articles, but do not provide it, as mentioned in the Introduction);
170 they are one of the few (two) publishers that take part in Crossref's text and data mining program. The
171 packages [fulltext](#) and [crminer](#) can be used to access Elsevier articles through Crossref's TDM program.
172 There's an interface to Scopus article search within [fulltext](#).

173 *arXiv/bioRxiv*

174 arXiv and bioRxiv are preprint publishers, the former in existence for many years, and the latter new
175 on the scene. Preprints are scholarly articles that are generally not peer-reviewed, but that for the most
176 part will later be published in a different peer-review publication. You can access articles from these
177 publishers through [fulltext](#). arXiv does provide a web API that we hook into; bioRxiv does not, but we
178 can get you articles nonetheless.

179 *Pubmed/PMC/Europe PMC*

180 Pubmed/PMC is a corpus/website of NIH funded research in the United States; while Europe PMC is
181 an equivalent for the European Union. You can access articles from Pubmed/PMC through [fulltext](#),
182 and for Europe PMC through [europepmc](#).

183 *Microsoft Academic Research*

184 Microsoft Academic Research (MAR) is a search engine for research articles. You can use their GUI
185 web interface to search, and they provide APIs for programmatic access. The R interface for MAR is
186 [microdemic](#); and [fulltext](#) hooks into [microdemic](#) as well for article search and abstract retrieval.

187 *Directory of Open Access Journals*

188 Directory of Open Access Journals (DOAJ) maintains data on open access journals, as well as some
189 portion of the articles in those journals. Thus, you can search for journals as well as articles with DOAJ.
190 The R interface for DOAJ is [jaod](#).

191 *JSTOR*

192 JSTOR's Data for Research program gives institutions with access to JSTOR, access to full text of
193 articles within JSTOR. There is no way however to make the interaction with JSTOR completely
194 programmatic, thus making reproducible research very difficult. Nonetheless, there is an R package
195 ([jstor](#)) for using data from JSTOR's Data for Research.

196 *ORCID*

197 ORCID (<https://orcid.org/>) is an organization keeping track of identifiers and metadata for researchers
198 around the world. Individuals can optionally maintain metadata on their scholarly works connected to
199 their account with ORCID. Thus, across all of ORCID, a significant cache of metadata is accruing on
200 scholarly works, their funding amounts, collaborators, etc., useful for bibliometrics research and more.
201 The R interface for ORCID is [rorcid](#).

202 *Citoid/Open Citation Corpus*

203 The Open Citation Corpus (<http://opencitations.net/>) holds records of which articles cite which other
204 articles, allowing for all important research on the scholarly web of citation. Citation data has been
205 very closely guarded until recently, but the largest publishers are still not contributing to the Open
206 Citation Corpus. The R interface to the Open Citation Corpus is [rcitoid](#).

207 *Fatcat*

208 Fatcat is a project from Ben Newbold of the Internet Archive Labs. It is a “versioned, publicly-editable
209 catalog of research publications: journal articles, conference proceedings, preprints, blog posts”. Fatcat
210 is currently does not have an R client, but is used inside of the [fulltext](#) package.

211 *SHERPA/RoMEO*

212 SHERPA/RoMEO (<http://sherpa.mimas.ac.uk/romeo/index.php>) aggregates and analyses publisher
213 open access policies and provides summaries of self-archiving permissions and conditions of rights given
214 to authors. The `[rromeo]` is an R interface to SHERPA/RoMEO.

215 *CORE*

216 CORE (<https://core.ac.uk/>) touts itself as the world's largest collection of open access research articles,
217 providing metadata on journals and articles, as well as access to the full text of articles. The `rcoreoa` R
218 package interfaces with the CORE API.

219 *Dissemin*

220 Dissemin (<https://dissem.in/>) detects papers behind pay-walls and invites authors to upload them
221 to an open repository. Dissemin provides metadata including links to open versions of articles. The
222 `[dissemr]` R package interfaces with the Dissemin API.

223 *Learn more*

224 To learn how to use the above packages, follow the links to get to documentation, and how to report
225 issues. The rOpenSci forum (<https://discuss.ropensci.org/>) is a good place to ask questions about these
226 packages.

227 **fulltext: a toolset for text mining in R**

228 `fulltext` is a general purpose R package for the data part of text mining: search for articles, get links to
229 articles, get article abstracts, and fetch full text of articles. The `fulltext` package is always adding
230 additional data sources as time allows (See Table 1). Starting from searching for articles, the outputs of
231 search can be fed into a function to get links to those articles, or to get abstracts for those articles, or
232 to fetch their full text. The following is a breakdown of the major distinct parts of `fulltext`.

233 *Search*

234 `ft_search()` provides search access to nine different data sources (PLOS, BMC, Crossref, Entrez, arXiv,
235 bioRxiv, Europe PMC, Scopus, Microsoft Academic), creating a mostly unified interface to all data
236 sources. The parts of each data source that are common are for the most part factored out into the
237 parameters of the `ft_search()` function: query term(s), pagination (number of results, result number
238 to start at). In addition, we allow the user to pass on data source specific options to refine the search
239 per data source.

240 With `ft_search()`, you can query any combination of the nine data sources at once. The returned
241 object is a list, with access to results of each data source by its name (e.g., `$plos`, or `$crossref`). For
242 each data source, the returned object does vary because the returned data from each data source widely
243 varies; for the most part `data.frame`'s are returned. For those data sources not queried, their slot is
244 empty.

245 One important aspect of the research result we highlight is the licenses in the returned data for each
246 data source.

```
x <- ft_search(query = 'ecology', from = c("plos", "crossref"))
```

247 The results for this PLOS search have all CC-BY licenses

```
x$plos
#> Query: [ecology]
#> Records found, returned: [47257, 10]
#> License: [CC-BY]
#>
#> id
#> 1 10.1371/journal.pone.0001248
#> 2 10.1371/journal.pone.0059813
#> 3 10.1371/journal.pone.0080763
#> 4 10.1371/journal.pone.0155019
#> 5 10.1371/journal.pone.0175014
#> 6 10.1371/journal.pone.0150648
#> 7 10.1371/journal.pone.0208370
#> 8 10.1371/journal.pcbi.1003594
```

```
#> 9 10.1371/journal.pone.0102437
```

```
#> 10 10.1371/journal.pone.0166559
```

248 Whereas the results for this Crossref search have mixed licenses

```
x$crossref
```

```
#> Query: [ecology]
```

```
#> Records found, returned: [164657, 10]
```

```
#> License: [variable, see individual records]
```

```
#>   archive          container.title    created deposited
#> 1  Portico                Ecology 2006-05-03 2018-08-04
#> 2  Portico                Ecology 2006-05-03 2018-08-04
#> 3    NA                Ecology 2006-05-03 2018-08-04
#> 4    NA                Ecology 2006-05-03 2018-08-04
#> 5    NA                Ecology 2006-05-03 2018-08-04
#> 6    NA                Ecology 2006-05-03 2018-08-04
#> 7    NA                Ecology 2006-05-09 2018-08-01
#> 8  Portico                Ecology 2017-04-26 2019-03-08
#> 9    NA Trends in Ecology & Evolution 2002-07-25 2017-06-14
#> 10   NA Journal of Industrial Ecology 2014-11-21 2017-06-23
#> Variables not shown: published.print (chr), published.online (chr), doi
#>   (chr), indexed (chr), issn (chr), issue (chr), issued (chr), member
#>   (chr), page (chr), prefix (chr), publisher (chr), reference.count
#>   (chr), score (chr), source (chr), title (chr), type (chr), url (chr),
#>   volume (chr), author (list), link (list), license (list), subject
#>   (chr), alternative.id (chr), subtitle (chr), reference (list)
```

249 You can dig into the license field for each article, with URLs holding information on each license

```
vapply(x$crossref$data$license, function(w) w$URL[1], "")
```

```
#> [1] "http://doi.wiley.com/10.1002/tdm_license_1.1"
```

```
#> [2] "http://doi.wiley.com/10.1002/tdm_license_1.1"
```

```
#> [3] "http://doi.wiley.com/10.1002/tdm_license_1"
```

```
#> [4] "http://doi.wiley.com/10.1002/tdm_license_1.1"
#> [5] "http://doi.wiley.com/10.1002/tdm_license_1"
#> [6] "http://doi.wiley.com/10.1002/tdm_license_1"
#> [7] "http://doi.wiley.com/10.1002/tdm_license_1"
#> [8] "http://doi.wiley.com/10.1002/tdm_license_1.1"
#> [9] "http://www.elsevier.com/tdm/userlicense/1.0/"
#> [10] "http://doi.wiley.com/10.1002/tdm_license_1.1"
```

250 *Links*

251 `ft_links()` provides two pathways to get links (URLs) for articles, with a choice of four different data
 252 sources (PLOS, BMC, Crossref, Entrez). First, you can use `ft_search()`, then pass the output of that
 253 function to `ft_links()`.

```
out <- ft_search(query = "ecology", from = "entrez")
ft_links(out)
#> <fulltext links>
#> [Found] 6
#> [IDs] ID_30964001 ID_30962485 ID_30962432 ID_30952928 ID_30674747
#>      ID_30674743 ...
```

254 Second, you can pass DOIs directly to `ft_links()`. Both end up at the same point, links for each
 255 article, if they could be found for the user selected data source.

```
# FIXME
ft_links(out$entrez$data$doi)
```

256 The biggest caveat with `ft_links()` is that we can't guarantee that the links will work. Link rot is one
 257 way in which the links may not work: link rot is when the URL does not point to the original content
 258 anymore, or fails altogether. Additionally, with Crossref, publishers can deposit URLs for articles, but
 259 they make change the URLs at some later date but not update the URLs with Crossref.

260 *Abstracts*

261 `ft_abstract()` provides access to article abstracts from four different data sources (PLOS, Scopus,
262 Microsoft Academic Research, Crossref). The only way to use the function is to pass article identifiers,
263 which are for the most DOIs.

264 The advantage of abstracts over full text is that abstracts can often be retrieved even for paywalled
265 articles. That is, you can have much broader coverage of the articles you're targeting relative to full
266 text.

267 If you are after abstracts, and you are already getting or already have full text, and if the articles are in
268 XML format, then you can use [pubchunks](#) to extract out the abstracts.

269 *Fetch full text*

270 `ft_get()` fetches full text of articles from many different data sources. From the DOIs that are passed
271 in to the function, we detect the publisher, and there are specific plugins for certain publishers: AAAS,
272 American Institute of Physics, American Society of Clinical Oncology, American Society for Microbiology,
273 arXiv, bioRxiv, BiomedCentral, Copernicus, Crossref, Elife, Elsevier, Pubmed/PMC via NCBI's Entrez,
274 Frontiers, IEEE, Informa, Instituto de Investigaciones Filologicas, American Medical Association,
275 Microbiology Society, PeerJ, Pensoft, PLOS, PNAS, Royal Society of Chemistry, ScienceDirect, Scientific
276 Societies, and Wiley.

277 If there's no built-in plugin for the publisher already, we use the FTDOI API (<https://ftdoi.org>) to try
278 to get the link for the full text of the article. If the FTDOI API doesn't bear fruit, we search Crossref
279 for a link to the full text. If Crossref doesn't have any full text links, we give up.

280 Since users can go through a lot of article requests, we cache successfully downloaded articles, and keep
281 that knowledge consistent across R sessions; all subsequent requests for the same article just use the
282 cached version. Additionally, all errors in `ft_get()` are collected in a data.frame in the output of the
283 function to help the user quickly determine what went wrong.

284 **Future directions**

285 Text mining will always be a complex task given all the layers involved: often temporal time-span of
286 research questions; varied permissions among researchers and their articles they're trying to access;
287 varied approaches to getting full text (xml vs pdf vs plain text); and more.

288 Programmatic text mining is a first step towards making text mining easier. The R ecosystem is an
289 especially good place to do text mining because there are many packages for text mining analysis, and
290 endless packages for any required statistical analyses. In addition, rOpenSci and others are building
291 up a set of packages in R for searching for and acquiring full text programatically to help make the
292 research workflow as reproducible as possible.

293 Future work for `fulltext` includes:

- 294 1. Adding more publisher plugins
- 295 2. Fine tuned user control over publishers
- 296 3. Improve VPN/proxy controls
- 297 4. Incorporate more search engines to help resolve URLs for fulltext versions
- 298 5. Improve documentation

299 With respect to what publishers can do to make text mining easier, publishers should:

- 300 1. provide XML if they have it
- 301 2. not change URL patterns so often, or at all
- 302 3. maintain consistent URL patterns among journals, years, etc.
- 303 4. keep their Crossref metadata up to date
- 304 5. open up their citation data

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307 **Data Accessibility**

308 All scripts and data used in this paper can be found in the permanent data archive Zenodo under
309 the digital object identifier (DOI). This DOI corresponds to a snapshot of the GitHub repository at
310 <https://github.com/ropensci/textmine>. Software can be found at <https://github.com/ropensci>, all
311 under MIT licenses.

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