text2sdg: An R package to Monitor Sustainable Development Goals from Text

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Abstract Monitoring progress on the United Nations Sustainable Development Goals (SDGs) is important for both academic and non-academic organizations. Existing approaches to monitoring SDGs have focused on specific data types; namely, publications listed in proprietary research databases. We present the **text2sdg** package for the R language, a user-friendly, open-source package that detects SDGs in any kind of text data using different existing or custom-made query systems. The **text2sdg** package thereby facilitates the monitoring of SDGs for a wide array of text sources and provides a much-needed basis for validating and improving extant methods to detect SDGs from text.

Introduction

The United Nations Sustainable Development Goals (SDGs) have become an important guideline for both governmental and non-governmental organizations to monitor and plan their contributions to social, economic, and environmental transformations. The 17 SDGs cover large areas of application, from ending poverty and improving health, to fostering economic growth and preserving natural resources. As the latest UN report (UN, 2022) attests, the availability of high-quality data is still lacking in many of these areas and progress is needed in identifying data sources that can help monitor work on these goals. Monitoring of SDGs has typically been based on economic and health data (e.g., https://sdg-tracker.org/; https://www.sdgindex.org/), which are often difficult and costly to gather. One attractive alternative that has emerged from recent scientometric efforts is to detect SDGs from text, such as academic publications. Digitized text represents an attractive resource for monitoring SDGs across a large number of domains because it is becoming widely available in various types of documents, such as news articles, websites, corporate reports, and social media posts. In light of this promise, we developed text2sdg, a freely available, open-source tool to enable the SDG-labeling of digitized text and facilitate methodological development in this area. In what follows, we first present some background on existing labeling systems developed to identify SDGs from text, and then provide an overview of the text2sdg package, showcase its use in a representative case study, and discuss the promise and limitations of the approach.

An overview of SDG labeling systems

The text2sdg package provides a user-friendly way to use any existing or custom-made labeling system developed to monitor the 17 SDGs in text sources. In the following, we will briefly introduce five existing labeling systems implemented in text2sdg: the Elsevier, Aurora, SIRIS, OSDG, and SDSN systems. See table 1 for overview of these labeling systems. We address custom-made labeling systems in a dedicated section below.

The most prominent SDG labeling systems has been developed by *Elsevier*. The Elsevier labeling system was integrated into the Times Higher Education Impact Rankings in 2019, which at the time compared 1,118 universities in their efforts to address the SDGs as measured by the frequency of SDG-related terms in their academic output. The Elsevier queries consist of a list of expert-vetted keywords that are combined using logical AND operators, implying that multiple keywords must be met to label a document as containing a certain SDG. The development of the queries started with an original list of keywords for each SDG that were iteratively fine tuned to maximize the number of identified papers closely reflecting the different SDGs. This involved cropping or combining keywords to reduce the number of irrelevant hits. A detailed report on the initial development of the Elsevier query system is provided by Jayabalasingham et al. (2019). Since the first version, the Elsevier labeling system has been iteratively improved, with the latest versions including additional information specific to academic publications and the Scopus database, such as identifiers of journal names or research areas. text2sdg implements the latest version without such additional identifiers to broaden the package's applicability beyond the Scopus database (Jayabalasingham et al., 2019).

The Aurora Universities Network's "Societal Impact and Relevance of Research" working group started to develop a labeling system in 2017 to increase the visibility of research into the SDGs. Aurora's queries were developed with the goal of identifying SDG-related academic publications included in the

Labeling system	SDGs covered	Query operators	Unique keywords per SDG (mean & SD)	Example query (SDG-01)
Elsevier Aurora SIRIS OSDG SDSN		OR	74.9 (21.7) 89.6 (31.6) 262 (148) 245 (236) 62.6 (16.6)	"extreme poverty" ("poverty") W/3 ("chronic*" OR "extreme") ("anti-poverty") AND ("poverty" OR "vulnerability") "absolute poverty" "End poverty"

Table 1: Overview of the Labeling Systems Implemented in **text2sdg**. Legend: OR—keywords are combined using logical ORs, implying that only the keywords must be matched to assign an SDG label; AND—keywords are combined using logical ANDs, implying that multiple keywords must be matched to assign an SDG label; wildcards—keywords are matched considering different keyword parts; proximity search—keywords must co-occur within a certain word window to assign an SDG label

Scopus database. Consequently, the syntax of Aurora queries is similar to the Scopus query language and the Elsevier system. However, in contrast to the Elsevier system, the queries combine keywords in a more complex fashion, recruiting Boolean- (AND, OR) and proximity operators (e.g., w/3, implying within 3 words). As a result, Aurora's keywords are more specific, possibly leading to a smaller number of false positives. The initial version of the Aurora system only included terms that appear in the SDG policy text of the targets and indicators defined by the United Nations. Subsequent versions expanded on this by including additional keywords that reflect academic terminology. text2sdg implements version 5.0 of the Aurora labeling system (Vanderfeesten et al., 2020a). This version represents an improvement on previous versions based on a survey study (Vanderfeesten et al., 2020b) and modifications inspired in other efforts, namely those from Elsevier (above) and SIRIS (introduced next).

The SIRIS labeling system (Duran-Silva et al., 2019) was created by SIRIS Academic as part of the "science4sdgs" project to better understand how science, innovation efforts, and technology related to the SDGs. The SIRIS queries were constructed in a five-step procedure. First, an initial list of keywords was extracted from the United Nations official list of goals, targets and indicators. Second, the list was manually enriched on a basis of a review of SDGrelevant literature. Third, a word2vec model that was trained on a text corpus created from the enriched keyword list was used to identify keywords that were semantically related to the initial list. Fourth, using the DBpedia API, keywords were added that, according to the Wikipedia corpus, had a categorical relationship with the initial list. Fifth, and finally, the keyword list was manually revised. The queries of the SIRIS labeling system primarily consist of individual keywords that occasionally are combined with a logical AND. text2sdg implements the only currently available version of the SIRIS labeling system (Duran-Silva et al., 2019).

The Open Source SDG (OSDG) project combines data from multiple sources to detect SDGs in text. Instead of developing yet another query system, OSDG's aim was to re-use and integrate existing knowledge by combining multiple SDG "ontologies" (i.e., query systems). OSDG has also made use of Microsoft Academic Graph to improve their results but because our query-based system cannot implement this procedure, we adopt the simpler ontology initially proposed by OSDG. The labeling system was based on central keywords in the SDG United Nations description (e.g. "sanitation" was classified into "SDG6") and then manually expanded with additional relevant keywords identified from a corpus of already labeled documents. The resulting keyword list only makes use of the OR operator. text2sdg implements the only currently available version of these queries (Bautista, 2019).

Finally, the Sustainable Development Solutions Network (SDSN, Sustainable Development Solutions Network (SDSN), 2021) labeling system contains SDG-specific keywords compiled in a collaborative effort by several universities from the Sustainable Development Solutions Network (SDSN) Australia, New Zealand & Pacific Network. This query system was developed to detect SDGs in large sets of university-related text data, such as course listings or research publications. The authors used United Nations documents, Google searches, and personal communications as sources for the keywords. This query system combines keywords with OR operators and does not make use of AND operators.

All in all, as can be seen in Table 1, the latter systems differ from the former three in the complexity of their queries: the Elsevier, Aurora, and SIRIS systems make use of keyword-combination queries and other criteria, such as proximity operators, whereas OSDG and SDSN only make use of keywords. As we will see in the results below, this has implications for the number of labels produced by the different systems.

Function Name	Description
detect_sdg	identifies SDGs in text using one of 5 labeling systems (Elsevier, Aurora, SIRIS, OSDG, SDSN).
detect_any	similar to detect_sdg but identifies SDGs in text using user-defined queries.
crosstab_sdg	crosstab_sdg takes the output of either detect_sdg or detect_any as input and determines correlations between either query systems or SDGs.
plot_sdg	takes the output of either detect_sdg or detect_any and produces adjustable barplots illustrating the hit frequencies produced by the different query systems.

Table 2: Overview of package functions

The text2sdg package

Designing text2sdg

Despite the effort put into developing various labeling systems and their great promise in addressing the SDG-related data scarcity, extant implementations of these approaches are not without shortcomings. First, the labeling systems were mostly developed to be used within academic citation databases (e.g., Scopus) and are not easily applied to other text sources. Second, existing implementations lack transparent ways to communicate which features are matched to which documents or how they compare between a choice of labeling systems. We alleviate these shortcomings by providing an open-source solution, text2sdg, that lets users detect SDGs in any kind of text using any of the above-mentioned systems or, even, customized, user-made labeling systems. The package provides a common framework for implementing the different extant or novel approaches and makes it easy to quantitatively compare and visualize their results.

Overview of text2sdg package

At the heart of the text2sdg package are the Lucene-style queries that are used to detect SDGs in text. These queries map text features (i.e., words or a combination of words) to SDGs. For example, a text that contains the words "fisheries" and "marine" would be mapped to SDG 14 (i.e., conserve and sustainably use the oceans, seas and marine resources for sustainable development) by the Aurora system. To enable the use of such queries in R, the text2sdg package recruits the corpustools (Welbers and van Atteveldt, 2021). corpustools has been built to implement complex search queries and execute them efficiently for large amounts of text. Based on this, text2sdg provides several functions that implement extant labeling systems, facilitate the specification of new labeling systems, and analyze and visualize search results. Table 2 gives an overview of the text2sdg core functions.

The main function of text2sdg is detect_sdg. The function runs some or all of the implemented labeling systems to identify SDGs in texts. The texts are provided to the function via the text argument as either a character vector or an object of class "tCorpus" from corpustools. All other arguments are optional. By default, the function runs only the Aurora, Elsevier, and SIRIS labeling systems to identify all 17 SDGs. However, both the the systems and the SDGs can be customized using the system and sdgs arguments, respectively. The function returns a tibble that includes one row per hit and has the following columns (and types):

- document (factor) index of element in the character vector or corpus supply for text
- sdg (character) labels indicating the matched SDGs
- system (character) the query system that produced the match
- query_id (integer) identifier of query in the query system
- features (character) words in the document that were matched by the query
- hit (numeric) running index of matches for each query system

Further details on the detect_sdg function and its output will be presented in the next section.

The detect_any function implements the same functionality as detect_sdg, but permits the user to specify customized or self-defined queries. These queries are specified via the code queries argument and must follow the syntax of the **corpustools** package. See Practical Considerations section for more details).

To support the interpretation of SDG labels generated by detect_sdg and detect_any, text2sdg further provides the plot_sdg and crosstab_sdg functions. The plot_sdg function visualizes the distribution of SDG labels identified in documents by means of a customizable barplot showing SDG frequencies for the different labeling systems. The crosstab_sdg function helps reveal patterns of label co-occurrences either across SDGs or systems, which can be controlled using the compare argument.

Demonstrating the functionality of text2sdg

To showcase the functionalities of the text2sdg package we analyze the publicly available p3 dataset of the Swiss National Science Foundation (SNSF) that lists research projects funded by the SNSF. In addition to demonstrating text2sdg, the case study will permit us to discuss practical issues concerning the labeling of SDGs, including relevant differences between labeling systems. The data and script to reproduce the analyses presented below can be found at https://osf.io/ekzhg/

Preparing the SNSF projects data

The SNSF projects data was downloaded from https://data.snf.ch/datasets. As of March 2022, the p3 database included information on 81,237 research projects. From the data, we removed 54,288 projects where the abstract was absent or not written in English. This left us with a total of 26,949 projects. To ready this data for analysis, we read it using the readr function of the readr package (Wickham et al., 2021), producing a tibble named projects. A reduced version of this tibble is included in the text2sdg package.

Using detect_sdg to detect SDGs

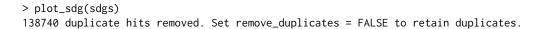
To label the abstracts in projects using text2sdg, we supply the character vector that includes the abstracts to the data argument of the detect_sdg function. Additionally, we make two optional settings. First, we specify that all five systems should be run, rather than the default of only Aurora, Elsevier, and SIRIS, by supplying a character vector of the systems' names to the systems argument. Second, we explicitly set the output argument to "features", which in contrast to output = "documents" delivers more detailed information about which keywords triggered the SDG labels.

```
# detect SDGs
> sdgs <- detect_sdg(text = projects,</pre>
                  systems = c("Aurora", "Elsevier", "SIRIS", "SDSN", "OSDG"),
                  output = "features")
> head(sdgs)
# A tibble: 6 × 6
 <dbl> <chr> <dbl> <chr> <dbl> <chr>
                                         <dbl>
                        392 sustainable
       1 SDG-01 SDSN
2
       1 SDG-02 SDSN
                         376 maize
                                            3
                         629 sustainable
       1 SDG-02 SDSN
                                            8
       1 SDG-08 OSDG
                        3968 work
                                            1
5
       1 SDG-08 SDSN
                          812 work
                                           11
                          483 research
       1 SDG-09 SDSN
                                            6
```

The above tibble produced by text2sdg contains for every combination of document, SDG, system, and query (columns 1 to 4), the query feature (keyword) that triggered the label (columns 5), and a hit index for a given system (column 6). The first row of the tibble thus shows that the query 392 within SDSN labeled document number 1 with SDG-01, because the document included the feature *sustainable*, and that this was the fourth hit produced by the SDSN system. It is important to note that, in other cases, multiple features of a query might be matched, which will result in multiple rows per combination of document, SDG, system, and query. This can be avoided by setting the output argument to "documents", in which case all features' hits of such combinations will be grouped into a single row.

Analyzing the SDG labels

To visualize the distribution of SDG labels across SDGs and systems in the sdgs tibble, we apply the plot_sdg function. By default, plot_sdg shows a barplot of the number of documents labeled by each of the SDGs, with the frequencies associated with the different systems stacked on top of each other. The function counts a maximum of one hit per document-system-SDG combination. Duplicate combinations resulting from hits by multiple queries or keywords in queries will be suppressed by default and the function returns a message reporting the number of cases affected.



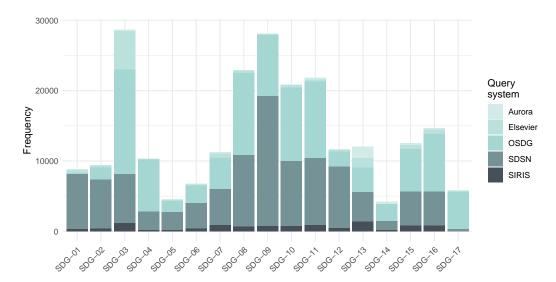


Figure 1: Default plot of distribution of detected SDGs.

The plot produced by plot_sdg (Figure 1) shows considerable differences in the frequency of different SDGs, with SDGs 3 ("Good Health and Well-Being") and 9 ("Industry, Innovation And Infrastructure") being most frequent and SDGs 5 ("Gender Equality") and 14 ("Life Below Water") being least frequent. Furthermore, there are substantial differences in the number of labels produced by different systems, with SDSN and OSDG having produced many more labels than the other three systems.

To customize the visualization of SDG frequencies, the plot_sdg function provides several additional arguments. For instance, by setting sdg_titles to TRUE, the SDG titles will be added to the annotation of the plot. Other arguments are normalize to show probabilities instead of frequencies, color to change the filling of bars, and remove_duplicates to eliminate duplicate document-system-SDG combinations. Furthermore, as plot_sdg is built on ggplot2 (Wickham, 2016), the function can easily be extended by functions from the ggplot2 universe. To illustrate these points, the code below generates a plot (Figure 2) that includes SDG titles and separates the results of the different SDG systems using facets.

The separation of systems better illustrates the results of systems that produce fewer hits and helps compare the results across systems. This reveals, for instance, that in the Elsevier system SDG 3 ("Good Health and Well-Being") was most prominent, whereas in the Aurora system this was SDG 13 ("Climate Action"). These results highlight that the different labeling systems do not necessarily agree concerning the assignment of SDGs to documents.

To quantify the commonalities and differences between labeling systems, text2sdg provides the crosstab_sdg function. The function evaluates the level of alignment across either systems (the default) or SDGs by calculating ϕ coefficients between the vectors of labels. We supply the hits argument of the function with the sdgs tibble containing the labels produced by detect_sdg. Note that the function only considers distinct combinations of documents, systems and SDGs, irrespective of whether the detect_sdg function was run using output = "documents" or output = "features".

> crosstab_sdg(sdgs)

```
Aurora Elsevier OSDG SDSN SIRIS
Aurora 1.0000000 0.3257805 0.1613242 0.1566679 0.3710827
Elsevier 0.3257805 1.0000000 0.2640787 0.2185416 0.3531881
OSDG 0.1613242 0.2640787 1.0000000 0.3705527 0.2242870
```

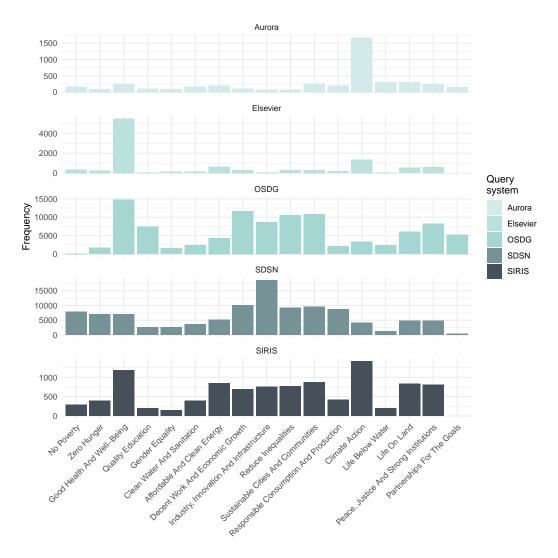


Figure 2: Distribution of detected SDGs facetted by system.

```
SDSN 0.1566679 0.2185416 0.3705527 1.0000000 0.2313963
SIRIS 0.3710827 0.3531881 0.2242870 0.2313963 1.0000000
```

The output of crosstab_sdg() for the SNSF projects reveals two noteworthy insights. First, the correspondence between the labels of different systems is rather small, as indicated by ϕ coefficients that are mostly smaller than .3. Second, there are two groups of systems that are more similar to one another. On the one hand, Elsevier, Aurora, and SIRIS, and, on the other hand, OSDG and SDSN. These groups correspond to differences in query operators, with the former three including AND operators in their queries, whereas the latter two do not.

It can further be informative to analyze the correlations between SDGs. To do this, we set the compare in crosstab_sdg() to "sdgs". The output below shows the result for the first six SDGs by setting sdgs = 1:6. It can be seen that certain pairs of SDGs—in particular, SDG-01 and SDG-02—cooccur more frequently. These results may provides insights into the co-occurrence structure of SDGs in the data at hand. However, these results can also highlight the importance of considering similarities between queries targeting different SDGs.

Practical considerations

Specifying user-defined labeling systems

The query systems implemented in **text2sdg** represent important efforts to systematize the monitoring of SDGs from text. Nevertheless, these efforts are still relatively young and validations of the systems are largely missing, creating a need for continued development. **text2sdg** supports the further development of new SDG labeling systems by providing the detect_any function. In this section, we provide additional detail on using this feature of **text2sdg**.

The detect_any function also uses **corpustools** as the back-end. This implies that new queries must be specified to match the syntax of **corpustools**. The syntax supports standard Boolean operators (AND, OR, and NOT), wildcard operators, and proximity search. Boolean operators control how different keywords are combined in a query. For instance, the query "marine OR fisheries" matches text that contains either these two words whereas the query "marine AND fisheries" only matches text that contains both these two words. The wildcard operators? and * allow the specification of variable word parts. For instance, the question mark operator? matches one unknown character or no character at all, e.g., "?ish" would match "fish", "dish", or "ish". The asterisk operator *, by contrast, matches any number of unknown characters, e.g., "*ish" would match "fish" but also "Swedish". Both wildcards can be used at the start, within or end of a term. Proximity search extends a Boolean AND, by requiring that two keywords have no more than defined distances to one another. For instance, "climate change" 3 specifies matches in which "climate" and "changed" both occur no more than three words apart. A complete description of the **corpustools** syntax is presented in the **corpustools** vignette and documentation.

To supply a user-defined labeling system to detect_any, the queries must be placed in a data. frame or tibble that additionally includes a column specifying the labeling system's name and a column of SDG labels corresponding to the queries.

- system (character) name of the labeling systems.
- queries (character) user-defined queries.
- sdg (integer) SDGs labels assigned by queries.

The example below illustrates the application of a user-defined labeling system using detect_any. First, a tibble is defined that includes three rows, one for each of three different queries stored in

the query column. The system is called "my_system" in the system column and each of the queries is assigned SDG-14 in the sdg column. Note that specification of the labeling system need not be made in R, but can easily be outsourced to a spreadsheet that is then processed into a tibble. Second, the system is supplied to the system argument of the detect_any function, along with the texts (here, the SNSF abstracts). The output is analogous to the output of the detect_sdg function (for brevity, we only show the first three lines of the output).

```
> # definition of query set
 my_system <- tibble::tibble(system = "my_system",</pre>
                            query = c("marine AND fisheries",
                                      "('marine fisheries') AND sea",
                                      "?ish"),
                            sdg = c(14, 14, 14))
 detect_any(text = projects,
          system = my_system)
# A tibble: 591 × 6
               system query_id features hit
  document sdg
  <fct> <chr> <chr>
                          <dbl> <chr> <int>
          SDG-14 my_system
                               3 wish
                                             122
2 134
          SDG-14 my_system
                                3 wish
3 241
          SDG-14 my_system
                               3 fish
                                              59
```

Applying text2sdg to non-English data

The queries of the labeling systems implemented by text2sdg are in English, implying that texts in other languages must first be translated to English. We assessed whether translation affects the reliability of SDG labels by making use of back translation. To this end, we first translated 1,500 randomly selected SNSF project abstracts from English to German and from German to English and then compared the labels of the original English and back-translated English abstracts. We carried out the translation using the DeepL translation engine (www.deepl.com/translator).

Table 3 shows the results of this analysis. Overall, the correlations as measured by the *phi*-coefficient are very high. The systems showed correlations above or equal to 0.88, with Elsevier showing the highest value of .93. Considering that our analysis involves not only one, but two translation steps—from German to English and back—these results suggest that **text2sdg** can be applied to non-English text with very high accuracy. One should note, however, that the quality of translation may vary between languages and translations engines.

Aurora	Elsevier	SIRIS	SDSN	OSDG
.91	.93	.88	.91	.91

Table 3: *phi*-coefficient between the labels for the original English text and the labels for the backtranslated (English-German-English) English text

Estimating the runtime of text2sdg

The analysis of text data can be computationally intense. To provide some guidance on the expected runtime of text2sdg for data with different numbers of documents and different document lengths, we carried out several experiments. For this purpose, we first simulated documents by concatenating 10, 100, 1,000, or 10,000 words drawn randomly according to word frequencies in Wikipedia and combined 1, 10, 100, or 1,000 thus-generated documents into simulated data sets. Then we evaluated the runtime of text2sdg separately by system for the simulated data sets.

Figure 3 shows the average runtime in seconds across 7,000 repetitions of each combination of document length and number of documents for each of the labeling systems. The results highlight noteworthy points. First, runtime is primarily a function of the number of words, irrespective of how words are distributed across documents. Second, the runtime per words decreases as the number of words increases, which is due to a constant overhead associated with optimizing the labeling systems' queries. Third, there are considerable differences in the runtime between systems, which is, in part, due to the functions' overhead and, in part, due to differences in number and complexity of queries. The fastest system is Elsevier, processing 10 million words in roughly one minute; the slowest system is SIRIS, processing 10 million words in about 40 minutes. Overall, these experiments highlight that

text2sdg can efficiently process large amounts of text, but also that some care should be exercised when dealing with extremely large or many texts. In such cases, it may be advisable to rely on more efficient labeling systems, such as Elsevier or SDSN.

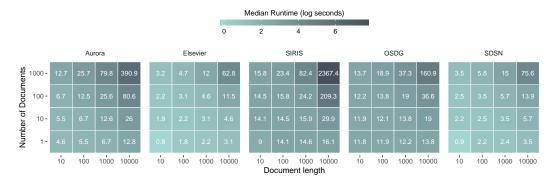


Figure 3: Runtime per seconds averaged across 7,000 runs for each cell. Color reflects log runtime.

Conclusion

In this article, we introduced a new R package, text2sdg, designed to help identify SDGs from text. The package promises to help detect SDGs in any kind of text sources using different existing or custom-made labeling systems. Our case study and additional analyses suggest that the approach can handle both sources in English as well as translations, allows user-friendly use of novel queries, and provides reasonably efficient performance for analysing large corpora.

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