COMP2521: Assignment 2
Simple Search Engines

[The specification may change, Please check the change log on this page.]

Change log:

- [04:35pm 23/Oct] : Instructions on how to submit the assignment are now available, see "Submission".
- [01:50pm 23/Oct] : Just a reminder, as mentioned in the lecture and in the hints, you need to use BST to implement your inverted index in 1B. See hints on **"How to Implement Ass2 (Part-1)"** , as discussed in the lecture.
- [01:50pm 23/Oct] : In 1C, as per the specs you need to "find page with **one or more search terms** and outputs (to stdout) top 30 pages in descending order of number of search terms found and then within each group, descending order of Weighted PageRank. The example for 1C is now appended to match with the sample data in 1B, to make it easy to understand.
- [02:40pm 11/Oct] : Due date is changeed to "11:59:00 pm Thursday Week-13", as discussed in the lecture.
- [08:00am 11/Oct] : In 1.B, for the expected output, earlier "url101 was at the end (incorrectly), revised to " mars url101 url25 url31 "
- [08:00am 11/Oct] : In the 1.A algorithm, "iteration++;" is moved to the end of the loop body to improve readability

Objectives

- to implement simple search engines using well known algorithms like (Weighted) PageRank and tf-idf, simplified versions for this assignment!
- to give you further practice with C and data structures (Graph ADT)
- to give you experience working in a team

Admin

Marks	20 marks (14 marks towards total course mark)
Group	This assignment is completed in **group of two**, based on your current lab group.
Due	11:59:00 pm Thursday Week-13
Late Penalty	2 marks per day off the ceiling. Last day to submit this assignment is 5pm Friday Week-13, of course with late penalty.
Submit	Read instructions in the "Submission" section below.

Aim

In this assignment, your task is to implement simple search engines using well known algorithms like (Weighted) PageRank and tf-idf, simplified for this assignment, of course!. You should start by reading the wikipedia entries on these topics. Later I will also discuss these topics in the lecture.

- PageRank (read up to the section "Damping factor")
- Weighted PageRank
- tf-idf

The main focus of this assignment is to build a graph structure, calculate Weighted PageRank, tf-idf, etc. and rank pages based one these values. You don't need to spend time crawling, collecting and parsing weblinks for this assignment. You will be provided with a collection of "web pages" with the required information for this assignment in a easy to use format. For example, each page has two sections,

- Section-1 contains urls representing outgoing links. Urls are separated by one or more blanks, across multiple lines.
- Section-2 contains selected words extracted from the url. Words are separated by one or more spaces, spread across multiple lines.

Hint: If you use `fscanf` to read the body of a section above, you do not need to impose any restriction on line length. I suggest you should try to use this approach - use `fscanf`! However, if you want to read line by line using say `fgets`, you can assume that maximum length of a line would be 1000 characters.

Hint: You need to use a dynamic data structure(s) to handle words in a file and across files, no need to know max words beforehand.

Example file `url31.txt`

```
#start Section-1

url2  url34  url1 url26
url52 url21
url74  url6 url82

#end Section-1

#start Section-2

Mars has long been the subject of human interest. Early telescopic observations
revealed color changes on the surface that were attributed to seasonal vegetation
and apparent linear features were ascribed to intelligent design.

#end Section-2
```

In Part-1: Graph structure-based search engine, you need to create a graph structure that represents a hyperlink structure of given collection of "web pages" and for each page (node in your graph) calculate Weighted PageRank and other graph properties. You need to create "inverted index" that provides a list of pages for every word in a given collection of pages. Your graph-structure based search engine will use this inverted index to find pages where query term(s) appear and rank these pages using their Weighted PageRank values.

In Part-2: Content-based search engine, you need to calculate tf-idf values for each query term in a page, and rank pages based on the summation of tf-idf values for all query terms. Use "inverted index" you created in Part-1 to locate matching pages for query terms.

In Part-3: Hybrid search engine, you need to combine both PageRank and tf-idf values in order to rank pages.

Additional files: You can submit additional supporting files, `*.c`and `*.h`, for this assignment. For example, you may implement your graph adt in files `graph.c` and `graph.h` and submit these two files along with other required files as mentioned below.

Sample files

- Sample1.zip

Part-1: Graph structure-based Search Engine

- Hints on **"How to Implement Ass2 (Part-1)"** , to be discussed in the lecture.

A: Calculate Weighted PageRanks

You need to write a program in the file `pagerank.c` that reads data from a given collection of pages in the file `collection.txt` and builds a graph structure using Adjacency Matrix or List Representation. Using the algorithm described below, calculate Weighted PageRank for every url in the file `collection.txt`. In this file, urls are separated by one or more spaces or/and new line character. Add suffix `.txt` to a url to obtain file name of the corresponding "web page". For example, file `url24.txt` contains the required information for `url24`.

Example file `collection.txt`

```
url25   url31 url2
   url102   url78
url32  url98 url33
```

Simplified Weighted PageRank Algorithm you need to implement (for this assignment) is shown below. Please note that the formula to calculate PR values is slightly different to the one provided in the corresponding paper (for explanation, read Damping factor).

```
PageRankW(d, diffPR, maxIterations)

    Read "web pages" from the collection in file "collection.txt"
    and build a graph structure using Adjacency List Representation

    N = number of urls in the collection

    For each url $p_i$ in the collection
        $PR(p_i;0) = \frac{1}{N}$
    End For

    iteration = 0;
    diff = diffPR;   // to enter the following loop

    While (iteration < maxIteration AND diff >= diffPR)

        $PR(p_i;t+1) = \frac{1-d}{N} + d * \sum_{p_j \epsilon M(p_i)} PR(p_j;t) * W^{in}_{(p_j,p_i)} * W^{out}_{(p_j,p_i)}$

        $diff = \sum_{i=1}^{N} Abs(PR(p_i;t+1) - PR(p_i;t))$

        iteration++;

     End While
```

Where,

- $M(p_i)$ is a set containing nodes (urls) with outgoing links to p_i (ignore self-loops and parallel edges)
- $W^{in}_{(p_j,p_i)}$ and $W^{out}_{(p_j,p_i)}$ are defined above (see above the link "Weighted PageRank")
- t and $(t+1)$ correspond to values of "iteration"

Note,

- For calculating $W^{out}_{(p_j,p_i)}$, if a **node** k **has zero out degree** (zero outlink), O_k **should be 0.5** (and not zero). This will avoid the issues related to division by zero.

Your program in `pagerank.c` will take three arguments (**d** - damping factor, **diffPR** - difference in PageRank sum, **maxIterations** - maximum iterations) and using the algorithm described in this section, calculate Weighted PageRank for every url.

For example,

```
% pagerank 0.85  0.00001  1000
```

Your program should output a list of urls in descending order of Weighted PageRank values (use format string `"%.7f"` ~~to 8 significant digits~~) to a file named `pagerankList.txt`. The list should also include out degrees (number of out going links) for each url, along with its Weighted PageRank value. The values in the list should be comma separated. For example, `pagerankList.txt` may contain the following:

Example file `pagerankList.txt`

```
url31, 3, 0.2623546
url21, 1, 0.1843112
url34, 6, 0.1576851
url22, 4, 0.1520093
url32, 6, 0.0925755
url23, 4, 0.0776758
url11, 3, 0.0733884
```

Sample Files for 1A

You can download the following three sample files with expected `pagerankList.txt` files. For your reference, I have also included the file "`log.txt`" which includes values of Win, Wout, etc. Please note that you do NOT need to generate such a log file.

Use format string `"%.7f"` to output pagerank values. Please note that your pagerank values might be slightly different to that provided in these samples. This might be due to the way you carry out calculations. However, make sure that your pagerank values match to say first 6 decimal points to the expected values. For example, say an expected value is 0.1843112, your value could be 0.184311x where x could be any digit.

All the sample files were generated using the following command:

```
% pagerank  0.85  0.00001  1000
```

- ex1
- ex2
- ex3

B: Inverted Index

You need to write a program in the file named `inverted.c` that reads data from a given collection of pages in `collection.txt` and generates an "inverted index" that provides a sorted list (set) of urls for every word in a given collection of pages. Before inserting words in your index, you need to "normalise" words by,

- removing leading and trailing spaces,
- converting all characters to lowercase,
- remove the following punctuation marks, if they appear at the end of a word:
  '.' (dot), ',' (comma), ';' (semicolon), ? (question mark)

You need to use BST to implement your inverted index in 1B, see hints on **"How to Implement Ass2 (Part-1)"** , as discussed in the lecture.

In each sorted list (set), duplicate urls are not allowed. Your program should output this "inverted index" to a file named `invertedIndex.txt`. One line per word, words should be alphabetically ordered, using ascending order. Each list of urls (for a single word) should be alphabetically ordered, using ascending order.

Example file `invertedIndex.txt`

```
design  url2 url25 url31
mars  url101 url25 url31
vegetation  url31 url61
```

C: Search Engine

Write a simple search engine in file `searchPagerank.c` that given search terms (words) as commandline arguments, finds pages with one or more search terms and outputs (to stdout) top 30 pages in descending order of number of search terms found and then within each group, descending order of Weighted PageRank. If number of matches are less than 30, output all of them.

Your program must use data available in two files `invertedIndex.txt` and `pagerankList.txt`, and must derive result from them. We will test this program independently to your solutions for "A" and "B".

Example:

```
% searchPagerank  mars  design
url31
url25
url2
url101
```

Part-2: Content-based Search Engine

In this part, you need to implement a content-based search engine that uses tf-idf values of all query terms for ranking. You need to calculate tf-idf values for each query term in a page, and rank pages based on the summation of tf-idf values for all query terms. Use "inverted index" you created in Part-1 to locate matching pages for query terms.

Read the following wikipedia page that describes how to calculate tf-idf values:

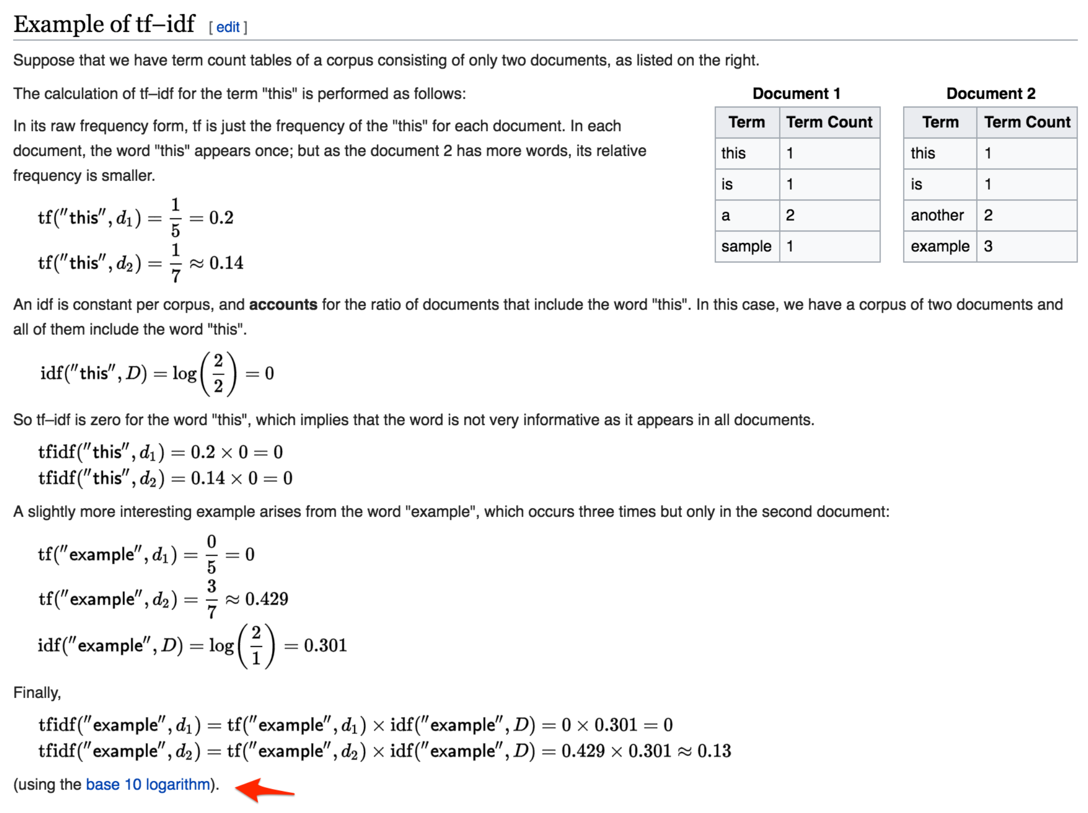
- tf-idf

For this assignment,

- calculate ***term frequency*** tf(t,d) adjusted for document length,
  i.e. (frequency of term t in d) / (number of words in d). See the example below.
- calculate ***inverse document frequency*** idf(t, D) by dividing the total number of documents by the number of documents containing the term, and then taking the logarithm of that quotient:

  $$\mathrm{idf}(\mathsf{this}, D) = \log \frac{N}{|\{d \in D : t \in d\}|}$$

  See the example below.



Example of tf–idf [edit]

Suppose that we have term count tables of a corpus consisting of only two documents, as listed on the right.

The calculation of tf–idf for the term "this" is performed as follows:

Document 1

Term	Term Count
this	1
is	1
a	2
sample	1

Document 2

Term	Term Count
this	1
is	1
another	2
example	3

In its raw frequency form, tf is just the frequency of the "this" for each document. In each document, the word "this" appears once; but as the document 2 has more words, its relative frequency is smaller.

$$\mathrm{tf}(''\mathsf{this}'', d_1) = \frac{1}{5} = 0.2$$
$$\mathrm{tf}(''\mathsf{this}'', d_2) = \frac{1}{7} \approx 0.14$$

An idf is constant per corpus, and **accounts** for the ratio of documents that include the word "this". In this case, we have a corpus of two documents and all of them include the word "this".

$$\mathrm{idf}(''\mathsf{this}'', D) = \log\left(\frac{2}{2}\right) = 0$$

So tf–idf is zero for the word "this", which implies that the word is not very informative as it appears in all documents.

$$\mathrm{tfidf}(''\mathsf{this}'', d_1) = 0.2 \times 0 = 0$$
$$\mathrm{tfidf}(''\mathsf{this}'', d_2) = 0.14 \times 0 = 0$$

A slightly more interesting example arises from the word "example", which occurs three times but only in the second document:

$$\mathrm{tf}(''\mathsf{example}'', d_1) = \frac{0}{5} = 0$$
$$\mathrm{tf}(''\mathsf{example}'', d_2) = \frac{3}{7} \approx 0.429$$
$$\mathrm{idf}(''\mathsf{example}'', D) = \log\left(\frac{2}{1}\right) = 0.301$$

Finally,

$$\mathrm{tfidf}(''\mathsf{example}'', d_1) = \mathrm{tf}(''\mathsf{example}'', d_1) \times \mathrm{idf}(''\mathsf{example}'', D) = 0 \times 0.301 = 0$$
$$\mathrm{tfidf}(''\mathsf{example}'', d_2) = \mathrm{tf}(''\mathsf{example}'', d_2) \times \mathrm{idf}(''\mathsf{example}'', D) = 0.429 \times 0.301 \approx 0.13$$

(using the base 10 logarithm).

Write a content-based search engine in file `searchTfIdf.c` that given search terms (words) as commandline arguments, outputs (to stdout) top 30 pages in descending order of number of search terms found and then within each group, descending order of summation of tf-idf values of all search terms found. **Your program must also output the corresponding summation of tf-idf along with each page, separated by a space and using format "%.6f", see example below**.

If number of matches are less than 30, output all of them. Your program must use data available in two files `invertedIndex.txt` and `collection.txt`, and must derive result from them. We will test this program independently to your solutions for Part-1.

Example:

```
% searchTfIdf  mars  design
url25  1.902350
url31  0.434000
```

Part-3: Hybrid/Meta Search Engine using Rank Aggregation

In this part, you need to combine search results (ranks) from multiple sources (say from Part-1 and Part-2) using "**Scaled Footrule Rank Aggregation**" method, described below. All the required information for this method are provided below. However, if you are interested, you may want to check out this presentation on "Rank aggregation method for the web".

Let T1 and T2 are search results (ranks) obtained using two different criteria (say Part-1 and Part-2). Please note that we could use any suitable criteria, including manually generated rank lists.

A weighted bipartite graph for scaled footrule optimization (C,P,W) is defined as,

- C = set of nodes to be ranked (say a union of T1 and T2)

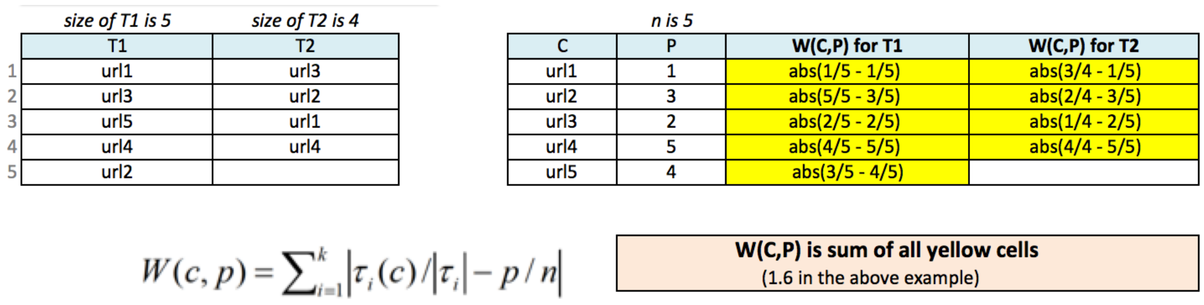
- P = set of positions available (say {1, 2, 3, 4, 5})
- **W(c,p)** is the **scaled-footrule distance** (from T_1 and T_2) of a ranking that places element 'c' at position 'p', given by

  $$W(c,p)=\sum_{i=1}^{k}\left|\tau_i(c)/|\tau_i| - p/n\right|$$

  where

  - n is the cardinality (size) of C,
  - $|T_1|$ is the cardinality (size) of T_1,
  - $|T_2|$ is the cardinality (size) of T_2,
  - $T_1(x_3)$ is the position of x_3 in T_1,
  - k is number of rank lists.

For example,



	size of T1 is 5	*size of T2 is 4*
	T1	T2
1	url1	url3
2	url3	url2
3	url5	url1
4	url4	url4
5	url2	

	n is 5		
C	P	W(C,P) for T1	W(C,P) for T2
url1	1	abs(1/5 - 1/5)	abs(3/4 - 1/5)
url2	3	abs(5/5 - 3/5)	abs(2/4 - 3/5)
url3	2	abs(2/5 - 2/5)	abs(1/4 - 2/5)
url4	5	abs(4/5 - 5/5)	abs(4/4 - 5/5)
url5	4	abs(3/5 - 4/5)	

$$W(c,p)=\sum_{i=1}^{k}\left|\tau_i(c)/|\tau_i| - p/n\right|$$

W(C,P) is sum of all yellow cells
(1.6 in the above example)

The **final ranking** is derived by finding **possible values of position 'P'** such that the **scaled-footrule distance is minimum**. There are many different ways to assign possible values for 'P'. In the above example P = [1, 3, 2, 5, 4]. Some other possible values are, P = [1, 2, 4, 3, 5], P = [5, 2, 1, 4, 3], P = [1, 2, 3, 4, 5], etc. For n = 5, possible alternatives are 5! For n = 10, possible alternatives would be 10! that is 3,628,800 alternatives. A very simple and obviously inefficient approach could use brute-force search and generate all possible alternatives, calculate scaled-footrule distance for each alternative, and find the alternative with minimum scaled-footrule distance.

If you use such a brute-force search, you will receive maximum of 65% for Part-3. However, you will be rewarded 100% for Part-3 if you implement a "smart" algorithm that avoids generating unnecessary alternatives, in the process of finding the minimum scaled-footrule distance. Please document your algorithm such that your tutor can easily understand your logic, and clearly outline how you plan to reduce search space, otherwise you will not be awarded mark for your "smart" algorithm! Yes, it's only 35% of part-3 marks, but if you try it, you will find it very challenging and rewarding.

Write a program `scaledFootrule.c` that aggregates ranks from files given as commandline arguments, and output aggregated rank list with minimum scaled footrule distance.

- **How to Get Started, Part-3**

Example, file rankA.txt

```
url1
url3
url5
url4
url2
```

Example, file rankD.txt

```
url3
url2
url1
url4
```

The following command will read ranks from files "rankA.txt" and "rankD.txt" and outputs minimum scaled footrule distance (using format %.6f) on the first line, followed by the corresponding aggregated rank list.

```
% scaledFootrule   rankA.txt  rankD.txt
```

For the above example, there are **two possible answers, with minimum distance of 1.400000**.

Two possible values of P with minnimum distance are:

```
C = [url1, url2, url3, url4, url5]
P = [1, 4, 2, 5, 3] and
P = [1, 5, 2, 4, 3]
```

By the way, you need to select any one of the possible values of P that has minium distance, so there could be multiple possible answers. Note that you need to output only one such list.

One possible answer for the above example, for `P = [1, 4, 2, 5, 3]` :

```
1.400000
url1
url3
url5
url2
url4
```

Another possible answer for the above example, `P = [1, 5, 2, 4, 3]` :

```
    1.400000
    url1
    url3
    url5
    url4
    url2
```

Please note that your program should also be able to handle multiple rank files, for example:

```
    % scaledFootrule   rankA.txt  rankD.txt  newSearchRank.txt  myRank.txt
```

Assignment-2 Group Creation

Later, instructions on how to create groups will be posted here.

Submission

Additional files: You can submit additional supporting files, `*.c` and `*.h`, for this assignment.

IMPORTANT: Make sure that your additional files (*.c) DO NOT have "main" function.

For example, you may implement your graph adt in files `graph.c` and `graph.h` and submit these two files along with other required files as mentioned below. However, make sure that these files do not have "main" function.

I explain below how we will test your submission, hopefully this will answer all of your questions.

You need to submit the following files, along with your supporting files (*.c and *.h):

- pagerank.c
- inverted.c
- searchPagerank.c
- searchTfIdf.c
- scaledFootrule.c

Now say we want to mark your `pagerank.c` program. The auto marking program will take all your supporting files (other *.h and *.c) files, along with `pagerank.c` and execute the following command to generate executable file say called pagerank. Note that the other four files from the above list (`inverted.c`, `searchPagerank.c`, `searchTfIdf.c` and `scaledFootrule.c`) will be removed from the dir:

```
% gcc -Wall -lm -std=c11  *.c  -o pagerank
```

So we will **not use your Makefile** (if any). The above command will generate object files from your supporting files and the file to be tested (say `pagerank.c`), links these object files and generates executable file, say `pagerank` in the above example. Again, please make sure that you **DO NOT have main function in your supporting files** (other *.c files you submit).

We will use similar approach to generate other four executables (from `inverted.c`, `searchPagerank.c`, `searchTfIdf.c` and `scaledFootrule.c`).

How to Submit

Go to the following page, select the tab "Make Submission", select "Browse" to select all the files you want to submit and submit ising "Submit" button. The submission system will try to compile each required file, and report the outcome (ok or error). Please see the output, and correct any error. If you do not submit a file(s) for a task(s), it will report it as an error(s).

You **can now submit this assignment**, click on "Make Submission" tab, and follow the instructions.

Plagiarism

This is a group assignment. You are not allowed to use code developed by persons other than in your group. In particular, it is not permitted to exchange code or pseudocode between groups. You are allowed to use code from the course material (for example, available as part of the labs, lectures and tutorials). If you use code from the course material, please **clearly acknowledge** it by including a comment(s) in your file. If you have questions about the assignment, ask your tutor.

Before submitting any work you should read and understand the sub section named ***Plagiarism*** in the section "Student Conduct" in the course outline. We regard unacknowledged copying of material, in whole or part, as an extremely serious offence. For further information, see the course outline.

-- end --