

# Programming Assignment 1

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Due: Thursday, April 17, 2013

## Overview

In this programming assignment, you will be applying knowledge that you have learned from Lecture 1-4 to build a simple indexing and retrieval system for a search engine. This assignment should be done in teams of two or individually. More specifically, it involves the following tasks:

1. Build an uncompressed index over a corpus of webpages from the stanford.edu domain (c.f. Sec. Corpus), and implement retrieval for Boolean conjunctive queries.
2. Build a compressed index over the same corpus, using variable length encoding and implement Boolean conjunctive queries.
3. Write up a report describing your program and answer a set of questions.
4. For extra credit, you are encouraged to implement other compression algorithms (e.g., gamma-encoding)

You are required to submit your code (which we will run with an auto-grader) and a write-up via Coursera. See later sections for more details.

## Corpus

The corpus you will be working with for this PA contains webpages from the stanford.edu domain. The data is available to download from the Coursera website under the Programming Assignments section. The total size of the corpus is about 170MBs.

There are 10 sub-directories (named 0-9) under the data directory. Each file under the sub-directory is the content of an individual webpage. You should assume that the individual file names are unique within each sub-directory, but not necessarily the case across sub-directories (i.e., the full path of the files are unique). All the HTML info has been stripped off from those webpages, so they only contain space-delimited words. You should not re-tokenize the words. Each consecutive span of non-space characters consists of a word token in the corpus.

## Task 1: Building an uncompressed index and retrieval (50%)

The first part of this assignment is to build an inverted index of this corpus, and implement Boolean conjunctive queries. In particular, you need to implement the blocked sort-based indexing (BSBI) algorithm. You should treat each sub-directory as a block, and only load one block in memory at a time when you build your index (note: you will be penalized if you construct the index by loading blocks of larger than one directory in memory at once). Note that we are abstracting away from the operating systems meaning of blocks. You can assume that each block is small enough to be stored in memory.

You will use Java for this programming assignment. You can find some sample skeleton code under the `cs276-pa1` directory inside the assignment package.

All of your submitted code for this PA should reside in a directory `cs276-pa1`. Under `cs276-pa1/task1` directory, you must supply two shell scripts, named `index.sh` and `query.sh`. Each script should invoke the necessary Java program to perform the indexing and retrieval tasks. Sample `index.sh` and `query.sh` scripts to invoke `cs276.assignments.Index` and `cs276.assignments.Query` Java programs can be found under `cs276-pa1/task1`. If you change these scripts, make sure that they can be invoked from the parent directory. For example,

```
sh task1/index.sh [input arguments - see below]
```

```
sh task1/query.sh [input arguments - see below]
```

### Indexing

The `index.sh` script should take two command-line arguments:

- `input_data_dir`: a string valued argument, describing the directory location of the input corpus data.
- `output_index_dir`: a string valued argument. This is the location of the output directory containing the generated index. You should assume the output directory does not exist yet.

In addition, the `index.sh` script should **only** print the total number of files in the corpus to stdout. At grading time, we will be invoking the `index.sh` script as follows.

```
sh task1/index.sh input_data_dir output_data_dir
```

We will then collect timing statistics on how long the indexing takes, the size of your generated index, and the amount of memory used when building the index. We will also verify that the total number of documents you output matches the expected count.

## Boolean conjunctive retrieval

The `query.sh` will take one command line argument, which is the directory location of the index you built. Your retrieval program should read from stdin a sequence of word tokens separated by space, which forms the Boolean conjunctive query. There could be any non-zero number of query terms. Your program should print to stdout the list of documents containing the query terms, one document file name on each line, sorted in lexicographical order. The document file name should only include the subdirectory name and the file name. For example,

```
0/crypto.stanford.edu_  
0/crypto.stanford.edu_DRM2002_  
1/crypto.stanford.edu_cs142_  
1/crypto.stanford.edu_cs155_hw_and_proj_
```

If the conjunctive query has no results (could also be caused by any of the terms in the query is not being found in the corpus), your program should output

```
no results found
```

to stdout.

It is important to make sure that you are **not loading the whole index into memory**. The whole point of indexing is that you can seek to the corresponding index position of a query term on the disk, and just read into memory the posting list of that term, without having to load the full index.

You are required to **implement efficient intersection of postings lists**. You will be penalized for using the programming language's set intersection operation. You are required to **order the terms by postings list length** to optimize query performance. You will be penalized if you do not implement this optimization. We will be invoking your script with the following command.

```
sh task1/query.sh index < query.txt
```

where `index` is the directory where your index resides and `query.txt` contains a list of query terms, all in one line.

## Toy dataset

It is usually a good idea to verify your programs output on a small toy dataset first during development. We have provided you with a small toy dataset and a set of sample queries and outputs, under the `toy_example` directory.

There is a script `grader.sh` under the same toy example directory. It is similar to the auto-grader script we use for final evaluation. You should be able run it to verify your program meets our input/output requirements. Also, a set of development queries and their outputs are given at the `dev_queries` and `dev_output` directories. The script `run_dev.sh` is provided to help you run these development queries.

## Grading

To ensure your index is built correctly, you will be tested on 20 Boolean conjunctive queries of one or multiple terms. For those queries, you will get 1.5% of the final grade for each query you answer correctly, for a total of 30% of your grade. You will earn another 20% if none of the following penalties apply to your program. You will be penalized by

1. 5% if your program does not load one block at a time in indexing (see our notes at the beginning of Task 1 description).
2. 5% if you do not order the query terms by postings list length in retrieval
3. 4% if your retrieval program loads the whole index into memory rather than simply loading the postings lists of just the query terms.
4. 3% if the total number of files your indexer outputs does not match the correct count.
5. 3% if the timing statistics of your retrieval algorithm are way out of the norm.

The maximum combined grades for this task is 50%.

## Task 2: Building a compressed index and retrieval (30%)

In the second task, you should build a compressed index using gap encoding with variable byte encoding for each gap. The input/output format and code structure is the same as Task 1, but you should provide scripts under directory `cs276-pa1/task2`. We will also use an auto-grader to build a compressed index with your program, and run a set of queries. Similar to Task 1, we will be invoking your scripts with

```
sh task2/index.sh [input arguments]
```

```
sh task2/query.sh [input arguments]
```

## Grading

Similar to Task 1, you will be tested on 20 conjunctive queries (1% for each query you answer correctly, for a total of 20%). And you will earn another 10% if none of the following penalties apply:

1. 5% if your compression algorithm does not achieve a reduction in index size.

2. 5% if your query response time with the compressed index is way out of norm.

The combined total grade of this task is 30%. Note that if your program does not implement the variable length encoding compression algorithm, you will receive **no credit** for this task.

### Task 3: Report (20%)

Please write up a 1-2 page report and submit alongside with your code. It should contain the following sections:

1. Briefly describe how your program is structured and the key steps in your indexing and retrieval algorithms. Make sure you report statistics on the size of the index (compressed and uncompressed), statistics of retrieval time for the development queries. (5%)
2. Answer each of the following questions: (5% each)
  - a) In this PA we asked you to use each sub-directory as a block and build index for one block at a time. Can you discuss the tradeoff of different sizes of blocks? Is there a general strategy when we are working with limited memory but want to minimize indexing time?
  - b) Is there a part of your indexing program that limits its scalability to larger datasets? Describe all the other parts of the indexing process that you can optimize for indexing time/scalability and retrieval time.
  - c) Any more ideas of how to improve indexing or retrieval performance?

### Grading

Your write-up will contribute to 20% of your final grade.

### Extra credit: experiment with additional compression methods (15%)

Implement one more index compression method (e.g., gamma-encoding), and supply your code in the same structure as Task 1 and 2 under directory `extra_credit`. Similar to Tasks 1 and 2, we will be invoking your scripts with

```
sh extra_credit/index.sh [input arguments]
```

```
sh extra_credit/query.sh [input arguments]
```

Also include in the report a discussion of the space/speed tradeoff of this additional compression method, in comparison to Task 2 and uncompressed index.

## Grading

You will be awarded 10% for answering 20 queries correctly (0.5% each). Note that, since the objective of this task is to achieve better compression rate, you'll receive 0% out of 10% if the size of your compressed index is larger than those of Tasks 1 and 2. 2% will be given for the space/speed discussion in your report. An extra 3% will be given to the top 10 teams who answer all 20 queries correctly and achieve the best compression rates. You will be penalized if the retrieval times are abnormally long. We will inspect your code for implementation correctness if necessary.

## Submission

We will use Coursera for grading and collecting the assignment. To submit the assignment, run `python submit.py`. You need to submit each task individually. Before submitting, make sure to write your and your partner's (if any) SUNet IDs in the `people.txt` file. The report should be in the same directory with name `report.pdf`. Note that all file names are in lowercase.

You also need to submit the code in a single .zip file, with filename identical to your and your partner's (if any) Stanford SUNetIDs concatenated by underscore. E.g., for students Jason Smith with Stanford ID `jsmith` and his partner Laura Page with Stanford ID `lpage`, their submission should be file `jsmith_lpage.zip`. If you are working alone on the assignment, the file name will just be `[Your SUNetID].zip`. The zipped file should be submitted via Coursera under Programming Assignments section. It should be submitted for the part 'Code' (use the Output Submission option and ignore the Additional Submission option). **Please make sure that** the unzipped `jsmith_lpage.zip` file should be a single directory `jsmith_lpage` with the following directory structure.

```

jsmith_lpage
├── cs276-pa1
│   ├── build.xml
│   ├── src
│   │   └── <any source files of your program>
│   ├── task1
│   │   ├── index.sh
│   │   ├── query.sh
│   │   └── <any additional files your program needs>
│   ├── task2
│   │   ├── index.sh
│   │   ├── query.sh
│   │   └── <any additional files your program needs>
│   └── extra_credit (optional)
│       ├── index.sh
│       ├── query.sh
│       └── <any additional files your program needs>
├── report.pdf
└── people.txt

```

Before you submit your assignment and code, it will be a good idea to run the `grader.sh` script on the toy data set, and the `run_dev.sh` script on the development queries. Note that the indexes for Task 1, Task 2 and Extra Credit have to be constructed from scratch (that is, they are not built upon indexes from other tasks). Also, remember that indexes in Task 2 and Extra Credit will need to be stored in binary format. If the submission script does not work on your shell/operating system, you can submit the assignment from the Stanford servers (for example, `corn.stanford.edu`).

**Final remark:** The submission may take some time, please make sure to leave enough time for submission.