News Search
- Mini IR project

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SECTIONS IN THE PRESENTATION

- Project idea
- Implementation overview
- Observations and Results

Project idea and detailed working

Brief Overview

- The project – “News Search” implements:
  - Clustering of news documents based on different zones
  - Exact top k weighted zonal ranked retrieval
  - Cluster based weighted zonal ranked retrieval
- Dataset: over 1 lakh news articles
- Implementation from scratch using C++, Openmp and CUDA

Dataset and document format

- Dataset:
  - "All the news" from Kaggle
  - News articles from around 15 American publications
  - Original format- .csv
  - Used a subset of it – 100093 docs

title:

publication:

author:

date:

year:

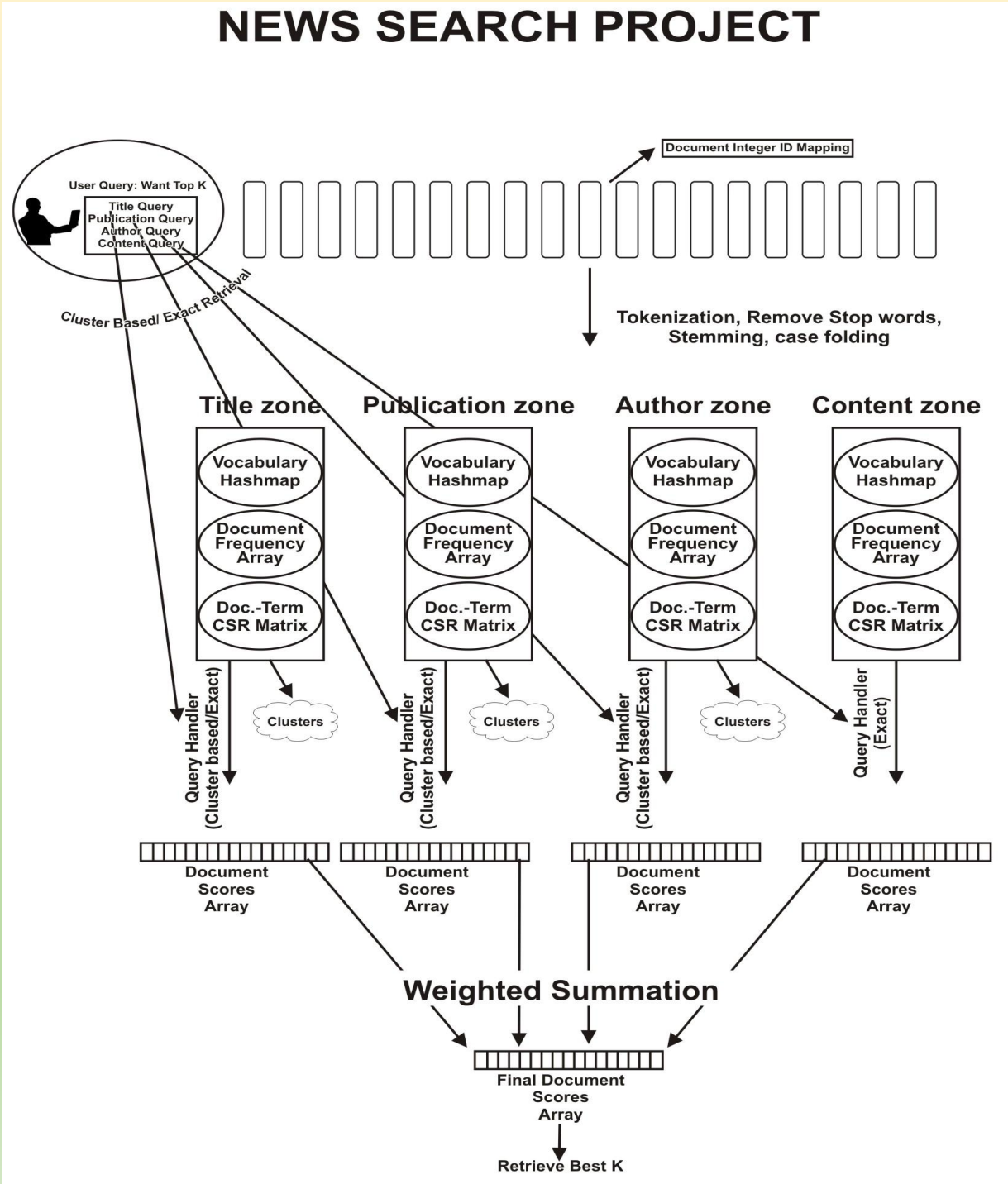
month:

url:

content:

- Document format used:
  - Separated .csv to different .txt files by writing a python converter
  - Zones taken into account for retrieval purpose: title, publication, author, content
  - Document names mapped to integer ids (0 to 100093) for ease of reference

Flow diagram



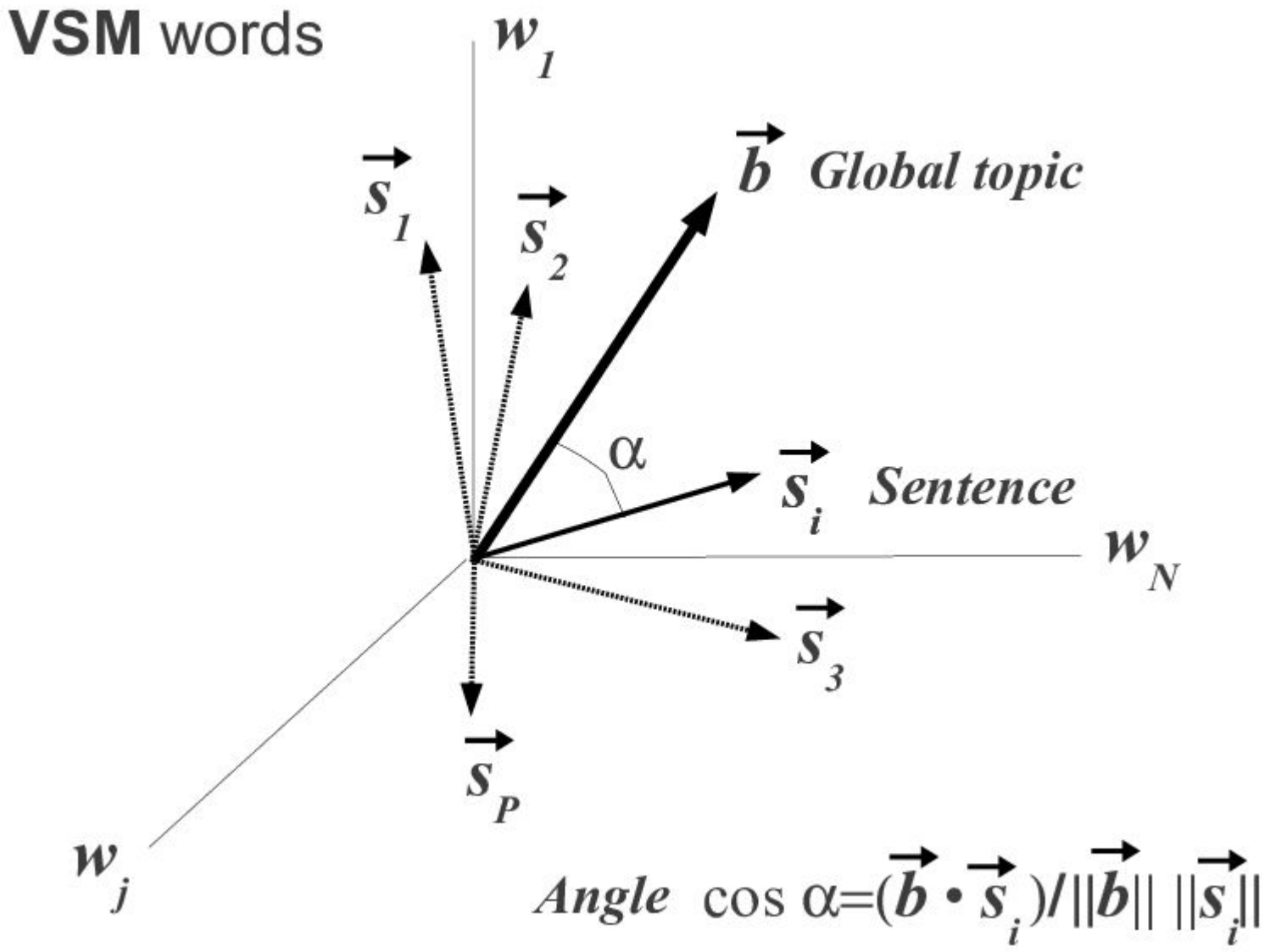
Tokenization, Case folding Stop words removal and Stemming

- Implemented Tokenizer using concept of regex
- Converted all word to lower case
- Removed stop words; used list by Gerard Salton from Cornell University
- Used Porter Stemmer for conversion to root form
- Stored information after this pre processing step for all 4 zones.
- Note: Avoided stemming and stop word removal for author and publication zone to retain exact names.

Zonal structures/Doc info storage

- Separate for each zone, stored everything in main memory
- Vocabulary
  - Hash map
  - Keys - unique terms
  - Values – term index - unique integer index (0 to vocab length)
- Doc-frequency array
  - Store doc-frequency for each word at array index = term index.
- Document – term matrix
  - i th row storing info about the doc having id = row index
  - j th column for term having term index/value = j in vocab hash map
  - (i,j) cell stores term frequency of term j in document i
  - Matrix stored in CSR format as it is a sparse matrix, and it can be fit into the main memory using CSR storage format.

Vector Space Model



Weighting scheme used:
log tf idf

weight for word W_i in doc-vector$_j$ = $(1+\log(tf_{i,j})).\log(N/doc\_freq_i)$

(In case tf = 0, weight = 0)

$tf_{i,j}$ = number of times the word W_i appears in doc j.

N = total number of docs in dataset

doc_freq_i = number of docs which contain W_i

Clustering

- Spherical k-means clustering algorithm
- Documents as document vectors following concept of vector space model; log tf-idf weighting scheme
- Clustered for zones- title, author and publication
- Also, implemented elbow method. Outputs dissimilarity score for num_clusters : 1 to 7, then user can choose a suitable number of clusters acc. to elbow point in the graph.

Exact top k retrieval

- Input free text queries from user for zone-title, author, publication and content
- Compute cosine similarity scores for all docs,zone_query pair for each of the zones
- Weighted summation of scores for corresponding documents
- Thus, obtained final set of scores for the user query
- Retrieve best k docs (in descending order of scores) – Ranked zonal retrieval

Cluster based retrieval

- Form of inexact top k retrieval
- Speeds up the retrieval process by reducing the number of docs to be matched with the zone query
- For each zone, found the cluster with the highest similarity to the zone query, and match with the docs only in that cluster. Allocate score 0 to all other docs for that zone query– this introduces inexactness
- For zone- content, simply compute scores for all doc,content_query pairs as did not cluster on basis of zone-content.
- Weighted summation of scores for corresponding documents
- Thus, obtained final set of scores for the user query
- Retrieve best k docs (in descending order of scores) – Ranked zonal retrieval

Implementation overview

- Openmp Implementation
- Cuda Implementation

Storage...

In both the cases,for each zone, the documents are stored in CSR matrix format.

Centroids and queries are taken as full vectors.

Openmp Implementation...

Parallelized parts of:

- cosine similarity score computation
- Document, centroid and query norms
- spherical k-means clustering (initializing seeds, assigning docs to clusters, recomputing centroids)
- query-handler(both cluster based and exact)
- elbow method (total within cluster dissimilarity)

Openmp Implementation...

Example: seeds initialization

```
18
19
20      void zone::initialize_centroids()
21      {
22          //get K seed points
23          //int array[num_clusters];
24          int* array = (int*)malloc(num_clusters*sizeof(int));
25          for(int i=0;i< num_clusters ;i++)
26          {
27                  array[i] = i;
28          }
29
30          //initialize centroids
31          #pragma omp parallel for //all local variables implicitly private
32          for(int i=0;i< num_clusters;i++)
33          {
34              int doc_index = array[i];
35              int start_ind_col_arr = matrix.row_ptrs[doc_index];
36              int end_ind_col_arr = matrix.row_ptrs[doc_index + 1];
37
38              #pragma omp parallel for
39              for(int j = start_ind_col_arr; j < end_ind_col_arr;j++)
40              {
41                  int word_ind = matrix.col_ind[j];
42                  centroids[i][word_ind] = 0;
43                  int tf = matrix.term_freq[j]; //log tf idf actually
44                  if(tf == 0)
45                      centroids[i][word_ind] = 0;
46                  else
47                  {
48                      centroids[i][word_ind] =  ( 1 + std::log10(double(tf)) )*std::log10(matrix.rows /doc_freq[word_ind]);
49
50                  }
51
52              }
53
54
55          }
56
57          free(array);
58
59      }
60
```

Cuda Implementation

CUDA kernels for parts of:

- k-means clustering
  - initializing seeds
  - assigning docs to clusters
  - recomputing centroids
- Document, centroid norms
- elbow method(total within cluster dissimilarity)
- query handler
  - cluster based
  - exact top k retrieval
- Scores summation

seeds initialization kernel

one warp per row of the csr matrix (or to initialize a seed)

All seeds are initialized in parallel.

```
370
371  __global__ void initialize_centroids_kernel( int num_clusters,int mat_rows, int mat_cols, int* mat_row_ptrs,
372   int* mat_col_ind, int* mat_term_freq, float* centroids, int* doc_freq)
373  {
374      int gid = blockDim.x * blockIdx.x + threadIdx.x;
375
376      int warp_index = (int)(gid / WARP_SIZE);  //(32 is warp size)
377
378      int centroid_index = warp_index;
379
380      if(centroid_index < num_clusters)
381      {
382          int doc_ind = centroid_index;
383
384          int start_ind_for_doc = mat_row_ptrs[doc_ind];
385
386          int end_ind_for_doc = mat_row_ptrs[doc_ind + 1];
387
388          int id_within_warp = gid % WARP_SIZE;
389
390          for(int k = start_ind_for_doc + id_within_warp; k < end_ind_for_doc; k = k + 32)
391          {
392              int tf = mat_term_freq[k];
393              int word_ind = mat_col_ind[k];
394
395              float weight = ( 1 + __log10f(tf))*(__log10f(mat_rows/doc_freq[word_ind]));
396
397              centroids[centroid_index*mat_cols + word_ind] = weight;
398          }
399      }
400  }
401
```

doc norms kernel

One warp per doc(row in csr matrix), then warp level reduction.

```
141
142 __global__ void compute_doc_norms_kernel(int mat_rows, int mat_cols, int* mat_row_ptrs, int* mat_col_ind,
143     int* mat_term_freq, int* doc_freq, float* doc_norms)
144 {
145     int gid = blockDim.x * blockIdx.x + threadIdx.x;
146
147     int warp_index = (int)(gid / WARP_SIZE);  //(32 is warp size)
148
149     int doc_ind = warp_index;
150
151     if(doc_ind < mat_rows)
152     {
153         int id_within_warp = gid%32;
154
155         int start_col_ind_for_doc = mat_row_ptrs[doc_ind];
156         int end_col_ind_for_doc = mat_row_ptrs[doc_ind + 1];
157
158
159         float temp = 0;
160
161         for(int a = start_col_ind_for_doc + id_within_warp; a < end_col_ind_for_doc; a = a + 32)
162         {
163             int tf = mat_term_freq[a];
164             int word_ind = mat_col_ind[a];
165             float weight = (1 + __log10f(tf))*(__log10f(mat_rows/doc_freq[word_ind]));
166             temp += weight*weight;
167         }
168
169         float val = temp;
170
171
172         for (int offset = 16; offset > 0; offset /= 2)
173         {
174             val += __shfl_down_sync(FULL_MASK, val, offset);
175         }
176
177         if(id_within_warp == 0)
178         {
179             doc_norms[doc_ind] = sqrt(val);
180         }
181
182     }
183 }
184
```

centroid norms kernel

Norms of all centroids are computed in parallel.

-- Used 2 D grid.

-- For centroid i , all threads with blockidx.y = i are used.

-- for each individual centroid, partial results are written into shared memory and then block reduce is called.

```
489
490  void zone::Compute_centroid_norms()
491  {
492
493      dim3 block(THREADS_PER_BLOCK);
494      int work_per_thread = 4;
495      int gridsize_x = ceil((double)matrix.cols / (double)(THREADS_PER_BLOCK * work_per_thread));
496      dim3 grid(gridsize_x,num_clusters);
497
498      float* gpu_buffer;
499      int buffer_size = gridsize_x*num_clusters;
500      cudaMalloc((void**)&gpu_buffer, buffer_size * sizeof(float));
501
502      dim3 grid2(1,num_clusters);
503
504      centroid_norms_kernel1 <<< grid , block >>> (matrix.cols, num_clusters , centroids_gpu, gpu_buffer);
505      centroid_norms_kernel2 <<< grid2 , block >>>(gridsize_x, num_clusters, gpu_buffer, centroid_norms_gpu);
506
507      cudaFree(gpu_buffer);
508
509  }
510
```

```
434
435
436  __global__ void centroid_norms_kernel1( int mat_cols,int  num_clusters ,float* centroids,float* buffer )
437  {
438      int dimgrid_x = gridDim.x;
439      int dimblock = blockDim.x;
440
441      int lid_x = threadIdx.x;
442      int gid_x = blockDim.x * blockIdx.x + threadIdx.x;
443
444      float tmp = 0;
445
446      int block_id_y = blockIdx.y;
447
448      for (int i = gid_x; i < mat_cols; i += dimgrid_x * dimblock)
449      {
450          tmp += centroids[block_id_y*mat_cols + i]*centroids[block_id_y*mat_cols + i];
451      }
452
453      __shared__ float tmp_work[THREADS_PER_BLOCK];
454      tmp_work[lid_x] = tmp;
455
456      __syncthreads();
457      block_reduce(tmp_work);
458
459      if (lid_x == 0)
460          buffer[ dimgrid_x*block_id_y +  blockIdx.x] = tmp_work[0];
461  }
462
463
```

centroid norms

kernel continued..

```
__global__ void centroid_norms_kernel2(int size_x ,int num_clusters, float* buffer,float* centroid_norms)
{
    int nt = blockDim.x;
    int tid = threadIdx.x;

    int block_id_y = blockIdx.y;

    float temp = 0;
    for(int i = tid; i < size_x; i += nt)
    {
        temp += buffer[block_id_y*size_x + i ];
    }

    __shared__ float tmp_work[THREADS_PER_BLOCK];
    tmp_work[tid] = temp;

    __syncthreads();
    block_reduce(tmp_work);

    if(tid == 0)
        centroid_norms[block_id_y] = sqrt(tmp_work[0]);
}
```

```
__device__ void block_reduce(float* data)
{
    int nt = blockDim.x;
    int tid = threadIdx.x;

    for (int k = nt / 2; k > 0; k = k / 2)
    {
        __syncthreads();
        if (tid < k)
        {
            data[tid] += data[tid + k];
        }
    }
}
```

RESULTS Folder:

As the code is executed,num_clusters and query is taken as input from the user and several files are produced.

Doc-names-index-MAP.txt

doc_term_csr_matrix_zone-TITLE.txt
doc_term_csr_matrix_zone-PUBLICATION.txt
doc_term_csr_matrix_zone-AUTHOR.txt
doc_term_csr_matrix_zone-CONTENT.txt

Elbow_Method_zone-TITLE.txt
Elbow_Method_zone-PUBLICATION.txt
Elbow_Method_zone-AUTHOR.txt

clustering_results_zone-TITLE.txt
clustering_results_zone-PUBLICATION.txt
clustering_results_zone-AUTHOR.txt

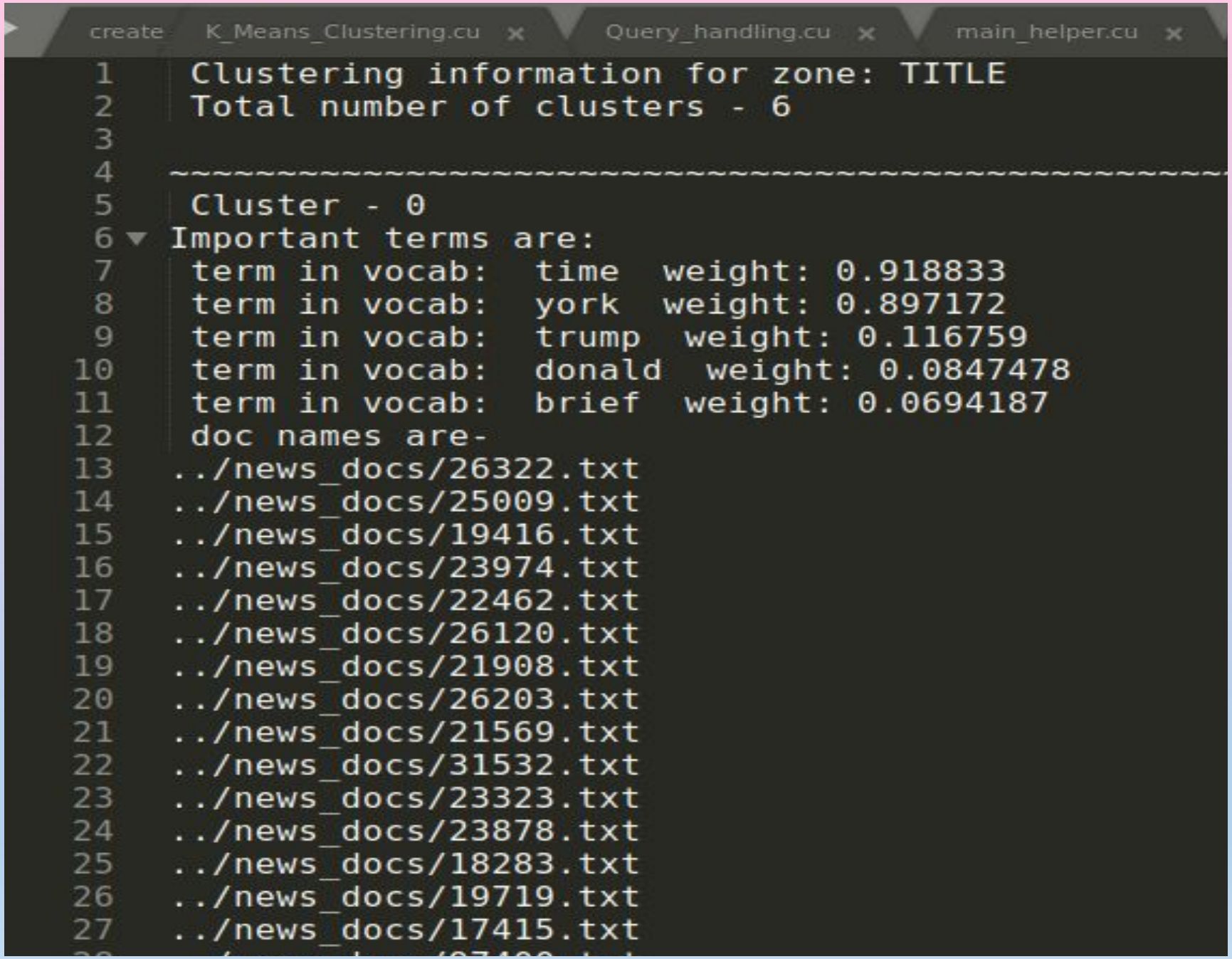
RETRIEVAL_RESULTS_round-0.txt
RETRIEVAL_RESULTS_round-1.txt
RETRIEVAL_RESULTS_round-2.txt
.
.
.

Elbow method example:

K_Means_Clustering | Query_handling.cu | main_helper.cu | myheader.h | *Elbow_Method_zone-TITLE.txt* | main.cp

```
elbow method for zone: TITLE

--------------------------------------------------------------------------------
K value = 1
 average dissimilarity is: 94415.9

--------------------------------------------------------------------------------
K value = 2
 average dissimilarity is: 93361.9

--------------------------------------------------------------------------------
K value = 3
 average dissimilarity is: 93054

--------------------------------------------------------------------------------
K value = 4
 average dissimilarity is: 92070.8

--------------------------------------------------------------------------------
K value = 5
 average dissimilarity is: 91449.1

--------------------------------------------------------------------------------
K value = 6
 average dissimilarity is: 90942.5

--------------------------------------------------------------------------------
K value = 7
 average dissimilarity is: 90635.7
```

Clustering results example:



Retrieval results example:

Cluster based

K_Means_Clustering. Query_handling.cu × main_helper.cu × myheader.h × RETRIEVAL_RESULT

```
1  Cluster based retrieval
2
3   zone : TITLE, free text query is: The First lady
4   zone : PUBLICATION, free text query is: New York TIMES
5   zone : AUTHOR, free text query is: David
6   zone : CONTENT, free text query is: Melania Trump
7  Top 7 docs are :
8  doc  name: ../news_docs/25778.txt  score: 1.61145 out of 4.00
9  doc  name: ../news_docs/18044.txt  score: 1.42212 out of 4.00
10 doc  name: ../news_docs/25059.txt  score: 1.42192 out of 4.00
11 doc  name: ../news_docs/20467.txt  score: 1.41313 out of 4.00
12 doc  name: ../news_docs/21451.txt  score: 1.41313 out of 4.00
13 doc  name: ../news_docs/22815.txt  score: 1.41313 out of 4.00
14 doc  name: ../news_docs/24268.txt  score: 1.41313 out of 4.00
15  The retrieval time is :129 milliseconds
16
```

Exact Retrieval

K_Means_Clustering. Query_handling.cu × main_helper.cu × myheader.h × RETRIEVAL_RESULTS-

```
1  Exact top k Retrieval
2
3   zone : TITLE, free text query is: Trump visits India
4   zone : PUBLICATION, free text query is: CNN
5   zone : AUTHOR, free text query is:
6   zone : CONTENT, free text query is: India Narendra Modi National
7  Top 4 docs are :
8  doc  name: ../news_docs/61213.txt  score: 1.58874 out of 4.00
9  doc  name: ../news_docs/58637.txt  score: 1.56299 out of 4.00
10 doc  name: ../news_docs/60771.txt  score: 1.55294 out of 4.00
11 doc  name: ../news_docs/60059.txt  score: 1.53572 out of 4.00
12  The retrieval time is :130 milliseconds
13
```

Observations and Results

Correctness check...

- Compared the results from plain sequential, openmp and cuda implementation.
- Manually opened the retrieved documents etc...

Vocabulary size - Full dataset

- Dataset: 100093 docs (414 MB)

- Vocabulary size:
  - Title zone: 38766
  - Publication zone: 35
  - Author zone: 6459
  - Content zone: 191184

Machine specifications

- cpu: Intel(R) Core(TM) i7-8550U CPU @ 1.80GHz, 1992 Mhz, 4 Core(s), 8 Logical Processor(s)

- gpu: Nvidia GeForce MX130

Zonal structures creation time

- Document parsing and creation of zonal structures-vocabulary, doc-frequency array, csr matrix structure: for all zones jointly takes around 12-13 minutes - for full dataset.

Runtime Comparison

DATASET (Number of docs)	Implementation:	K Clustering- TITLE		K Clustering- PUBLICATION		K Clustering- AUTHOR		Cluster based retrieval	Exact top k retrieval
1000	Sequential	6	1241 millisec	6	12 millisec	7	213 millisec	175 millisec	179 millisec
	OpenMp		684 millisec		17 millisec		80 millisec	55 millisec	71 millisec
	CUDA		9 millisec		6 millisec		4 millisec	7 millisec	3 millisec
5000	Sequential	7	80.7 sec	6	44 millisec	2	237 millisec	1454 millisec	2000 millisec
	OpenMP		25.6 sec		76 millisec		86 millisec	371 millisec	415 millisec
	CUDA		53 millisec		3 miilisec		7 millisec	14 millisec	14 millisec

Runtime Comparison

DATASET (Number of docs)	Implementation:	K Clustering- TITLE		K Clustering- PUBLICATION		K Clustering- AUTHOR		Cluster based retrieval	Exact top k retrieval
10000	Sequential	6	4.57 minutes	6	73 millisec	2	615 millisec	4122 millisec	6065 millisec
	OpenMp		80.8 sec		115 millisec		245 millisec	1406 millisec	1175 millisec
	CUDA		91 millisec		6 millisec		2 millisec	40 millisec	20 millisec
25000	Sequential	6	impractical	6	---	2	---	---	21.634 sec
	OpenMP		very very slow		---		---	---	6.145 sec
	CUDA		348 millisec		6 millisec		3 millisec	45 millisec	51 millisec

Runtime Comparison

DATASET (Number of docs)	Implementation:	K Clustering- TITLE		K Clustering- PUBLICATION		K Clustering- AUTHOR		Cluster based retrieval	Exact top k retrieval
50000	Sequential	6	impractical	6	----	2	----	---	1.341 minutes
	OpenMp		impractical		----		----	---	16.390 sec
	CUDA		597 millisec		20 millisec		5 millisec	85 millisec	82 millisec
100093 docs(FULL DATASET)	**Sequential**	6	**impractical**	6	---	2	---	---	**2.66 min**
	OpenMP		**impractical**		---		---	---	**48 sec**
	CUDA		**1159 millisec**		**30 millisec**		**14 millisec**	**129 millisec**	**130 millisec**

Limitations...

For larger datasets, we will run out of memory.

References…

- An Introduction to Information Retrieval by Christopher D. Manning, Prabhakar Raghavan, Hinrich Schütze –Chapter-16 : Flat clustering, Chapter-6: Scoring, term weighting and the vector space model

- Salton, Gerard. 1971a. Cluster search strategies and the optimization of retrieval effectiveness.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