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Csc212 Data structure

CSC212 project

Section no.66510
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1. Explanation of our search engine:

In our code, we implement a search engine that stores and retrieves information from documents.
Components:

1.1 Term and TermRank Classes:

- The classes represent the words (terms), and information associated with them.
- Term: Stores a word along with a boolean array indicating whether the word appears in any documents.
- TermRank: identifies the frequency with which a word appears in each document.

1.2 Inverted index

- This is a data structure that maps words to the documents they appear in.

  Different implementations are provided:

- Inverted index with BST: Uses a BST to store words and their associated Term objects.
- Inverted index with AVL: Uses an AVL tree for efficient storage and retrieval.
- Inverted index with ranking: Stores word frequencies for each document

1.3 Search Engine Class:

- Loads data from a specified file

  Provides methods for:

- Term Retrieval: Finds documents containing a specific word or term.
- Boolean Retrieval: Retrieves documents based on Boolean operations such as AND, OR, and NOT.
- Ranked Retrieval: Orders documents by relevance using word frequency or ranking algorithms.
- Indexing Information: Provides details about indexed documents and their associated tokens.

2. How the code works :

2.1 Indexing Process:

- Documents are analyzed and processed.
- Words are extracted and organized into suitable data structures, such as a simple index, inverted index, or ranked inverted index.
- For ranked retrieval, word frequencies are calculated and recorded.

2.2 Searching:

- Term Retrieval: The search engine locates the specified word in the data structure and retrieves the corresponding documents.
- Boolean Retrieval: The search engine analyzes the query, applies Boolean operators (AND, OR) to combine results for multiple terms, and returns matching documents.
- Ranked Retrieval: The search engine computes relevance scores for documents using word frequencies or other ranking methods and provides the highest-ranked results.

3. Performance analysis

3.1 Class inverted index

The Inverted_Index class is another way to implement an inverted index. It stores words and the documents that contain those words. Unlike the previous implementation, this one uses a linked list to organize the words and their corresponding document IDs.

Method: adddocument()

Code	Frequency	Total
if (DocumentIndex.empty()) {}	1	O(1)
DocumentIndex.findFirst();	1	O(1)
while (!DocumentIndex.last()) {}	n−1	O(n-1)
if (DocumentIndex.retrieve().word.word.compareTo(word) == 0) {}	n-1	O((n-1)*c)
DocumentIndex.insert(term);	1	O(1)
total		O(n*c)

Method: found()

Code	Frequency	Total
if (DocumentIndex.empty()) {}	1	O(1)
DocumentIndex.findFirst();	1	O(1)
while (!DocumentIndex.last()) {}	n−1	O(n-1)
if (DocumentIndex.retrieve().word.word.compareTo(word) == 0) {}	n-1	O((n-1)*c)
total		O(n*c)

Method: AND_OR_Function

Code	**Frequency**	**Total Complexity**
if (!string.contains(" OR ") && !string.contains(" AND ")) {}	1	**O(k)**
String[] AND_ORs = string.split(" OR ");	1	**O(k)**
result = AND_Function(AND_ORs[0]);	1	**O(t*h)**
for (int i = 1; i < AND_ORs.length; i++) {}	t-1	**O((t−1)·(h+50))**
Total		**O(k+t·(h+50))**

Method: AND_Function

Code	**Frequency**	**Total Complexity**
String[] ANDs = string.split(" AND ");	1	**O(k)**
if (this.found(ANDs[0].toLowerCase().trim())) {}	1	**O(h)**
for (int i = 1; i < ANDs.length; i++) {}	t - 1	**O((t−1)·(h+50))**
Total		**O(k+t*h+50t)**

Method: OR_Function

Code	Frequency	Total Complexity
String[] ORs = string.split(" OR ");	1	**O(k)**
if (this.found(ORs[0].toLowerCase().trim())) {}	1	**O(h)**
for (int i = 1; i < ORs.length; i++) {}	t- 1	**O((t−1)·(h+50))**
Total		**O(k+t·h+50t)**

Method: printDocment()

Code	Frequency	Total Complexity
if (DocumentIndex.empty())	1	**O(1)**
while (!this.DocumentIndex.last()) {}	n−1	**O(n−1)**
System.out.println(DocumentIndex.retrieve())	n	**O(n)**
Total		**O(n)**

Total inverted index:

Code	Time Complexiy
adddocument()	**O(n·c)**
found	**O(n·c)**
AND_OR_Function	**O(k+t·(h+50))**
AND_Function	**O(k+t·(h+50))**
OR_Function	**O(k+t·(h+50))**
printDocment	**O(n)**
Total	**O(k+t·h+50t+n·c)**

3.2 Class Inverted index BST:

The Inverted_Index_BST class is an implementation of an inverted index using a Binary Search Tree (BST). Data structures such as inverted indexes are commonly used in search engines to map terms (words) to documents

Code	Frequency	Total complexity
BST<String,Term> DocumentindexBST;	1	O (1)
public Inverted_Index_BST () { DocumentindexBST = new BST<>(); }	1	O (1)
public int size() { return DocumentindexBST.size(); }	1	O (1)

Method: size ()

Code	Frequency	Total complexity
public int size () {	1	O (1)
return DocumentindexBST.size();	1	O (1)

Method: adddocument(int docID, String word)

Code	Frequency	Total complexity
public boolean adddocument(int docID, String word) {	1	O (1)
if (DocumentindexBST.empty()) {	1	O (1)
term = new Term(); term.setVocabulary(new Vocabulary(word));	1	O(1)
term.add_documentID(docID);	1	O(1)
DocumentindexBST.insert(word, term);	1	O (log n)
if (DocumentindexBST.find(word)) {	1	O (log n)
term = DocumentindexBST.retrieve(); term.add_documentID(docID);	1	O (log n)
DocumentindexBST.update(term);	1	O(log n)

Method: found (String word)

Code	Frequency	Total complexity
public boolean found (String word) { return DocumentindexBST.find(word); }	1	O (log n)

Method: printDocument ()

Code	Frequency	Total complexity
public void printDocument() { DocumentindexBST.Traverse(); }	1	O(n)

Method: AND OR Function

Code	Frequency	Total complexity
if (! string.contains(" OR ") && ! string.contains(" AND "))	1	O(k)
string = string.toLowerCase().trim();	1	O(k)
if (this.found(string)) result = DocumentindexBST.retrieve().getDocs()	1	O(log n)
return result;	1	O(1)
if (string.contains(" OR ") && string.contains(" AND ")) {	1	O(k)
String[] AND_ORs = string.split(" OR ");	1	O(k)
result = AND_Function(AND_ORs[0]);	1	O(m·logn)
for (int j = 0 ; j < 50 ; j++) result [j] = result[j] || tempResult[j];	Loop through subqueries and combine results using "OR".	O(s·(m·logn+50))

Method: AND Function

Code	Frequency	Total complexity
String [] ANDs = string.split(" AND ");	1	O(k)
if (this.found(ANDs[0].toLowerCase().trim())) {	1	O(log n)
for (int j = 0 ; j < 50 ; j++) result [j] = result[j] && tempResult[j];	t	O(t·(logn+50))

Method: OR Function

Code	Frequency	Total complexity
String [] ORs = string.split(" OR ");	1	O(k)
if (this.found(ORs[0].toLowerCase().trim())) {	1	O(log n)
for (int j = 0 ; j < 50 ; j++) result [j] = result[j] || tempResult[j];	Loop through subqueries and combine results using "OR".	O(t·(logn+50))

Method	Total
size()	O (1)
adddocument()	O(logn)
found()	O(logn)
printDocument()	O(n)
AND_OR_Function()	O(k+s·m·logn)
AND_Function()	O(k+t·logn)
OR_Function()	O(k+t·logn)
O(total)=	O(d·w·logn+k+s·m·logn)
O(average)=	O(d·w·logn+n+q·k+s·q·m·logn+2·s·q·k+2·s·q·t·logn)

3.3 class Index:
An inverted index is a data structure that maps words to the documents where those words appear. This allows for efficient searching of text documents. Instead of scanning every document for a specific word, we can quickly look up the word in the index and retrieve the documents associated with it.

code	frequency	total
public class Index {	0	0
class Document {	0	0
int documentID;	1	1
LinkedList<String> wordList;	1	1
public Document() {	0	0
documentID = 0;	1	1
wordList = new LinkedList<String>();	1	1
}		
total		O(1)

Method:addWord

code	frequency	total
wordList.insert(word);	1	O(1)
total		O(1)

Method:hasWord

code	frequency	total
if (wordList.empty())	1	O(1)
wordList.findFirst();	1	O(1)
while (i < wordList.size) {	Loops over k words	O(k)
if (wordList.retrieve().compareTo(word) == 0)	executes up to k	O(k)
wordList.findNext();	executes up to k	O(k)
total		O(k)

Constructor Index()

code	frequency	total
documents = new Document[50];	1	O(1)
while (i < documents.length) {	Loops 50 times	O(n)
documents[i] = new Document();	Executes 50 times	O(n)
documents[i].documentID = i;	Executes 50 times	O(n)
total		O(n)

Method: addToDocument

code	frequency	total
documents[documentID].addWord(word);	1	O(1)
total		O(1)

Method: displayDocument

code	frequency	total
if (documents[documentID].wordList.empty())	1	O(1)
documents[documentID].wordList.findFirst();	1	O(1)
while (i < documents[documentID].wordList.size) {	K(words)	O(K)
System.out.print(documents[documentID].wordList.retrieve() + " ");	k	O(K)
documents[documentID].wordList.findNext();	k	O(K)
total		O(K)

Method: retrieveDocuments

code	frequency	total
while (i < matches.length) {	n	O(n)
matches[i] = false;	n	O(n)
while (i < matches.length) {	n	O(n)
if (documents[i].hasWord(word))	n	O(n*k)
matches[i] = true;	n	O(n)
total		O(n*k)

Methode AND_OR_Functio

code	frequency	total
if (!query.contains(" OR ") && !query.contains(" AND ")) {	1	O(1)
boolean[] results = retrieveDocuments(query.toLowerCase().trim());	1	O(n*k)
if (query.contains(" OR ") && query.contains(" AND ")) {	1	O(q)
boolean[] results = AND_Function(subQueries[0]);	1	O(h*n*k)
while (i < subQueries.length) { boolean[] subResults = AND_Function(subQueries[i]);	s-1 subQueries	O((s-1)*h*n*k)
while (j < 50) { results[j] = results[j] || subResults[j];		SubResults[j]
total		O(h*n*k *s)

Method: AND_Function

code	frequency	total
String[] andParts = query.split(" AND ");	1	O(h)
boolean[] results = retrieveDocuments(andParts[0].toLowerCase().trim());	1	O(n*k)
while (i < andParts.length) { boolean[] subResults = retrieveDocuments(andParts[i].toLowerCase().trim());	h-1	O((h-1)*n*k)
while (j < 50) { results[j] = results[j] && subResults[j];	n*h	O(n*k)
total		O(h*n*k)

Method: OR_Function

code	frequency	total
String[] orParts = query.split(" OR ");	1	O(h)
boolean[] results = retrieveDocuments(orParts[0].toLowerCase().trim());	1	O(n*k)
while (i < orParts.length) {boolean[] subResults = retrieveDocuments(orParts[i].toLowerCase().trim());	h-1	O((h-1)*n*k)
while (j < 50) { results[j] = results[j] || subResults[j];		subResults[j];
total		O(h*n*k)

Total:

method	total
Index()	O(n)
HasWord()	O(k)
addToDocument ()	O(1)
DisplayDocument()	O(n*k)
RetrieveDocuments()	O(n*k)
AND_OR_Function()	O(m*k)
AND_Function()	O(m*(n*k))
OR_Function()	O(m*(n*k))
total	O(m*(n*k))

Comparison

- **Class Index: O(m(n*k)) is the linear complexity of the simplest structure. It works well with tiny datasets but might not work well with big ones.**
- **Class Inverted Index: Performs better than Class Index when handling more frequent document updates, but is a little more complicated because of t*h and n*c.**
- **The best way to achieve scalability because operations for updates and searches grow logarithmically (log n). Large datasets benefit greatly from the BST's logarithmic performance, despite its higher constants.**

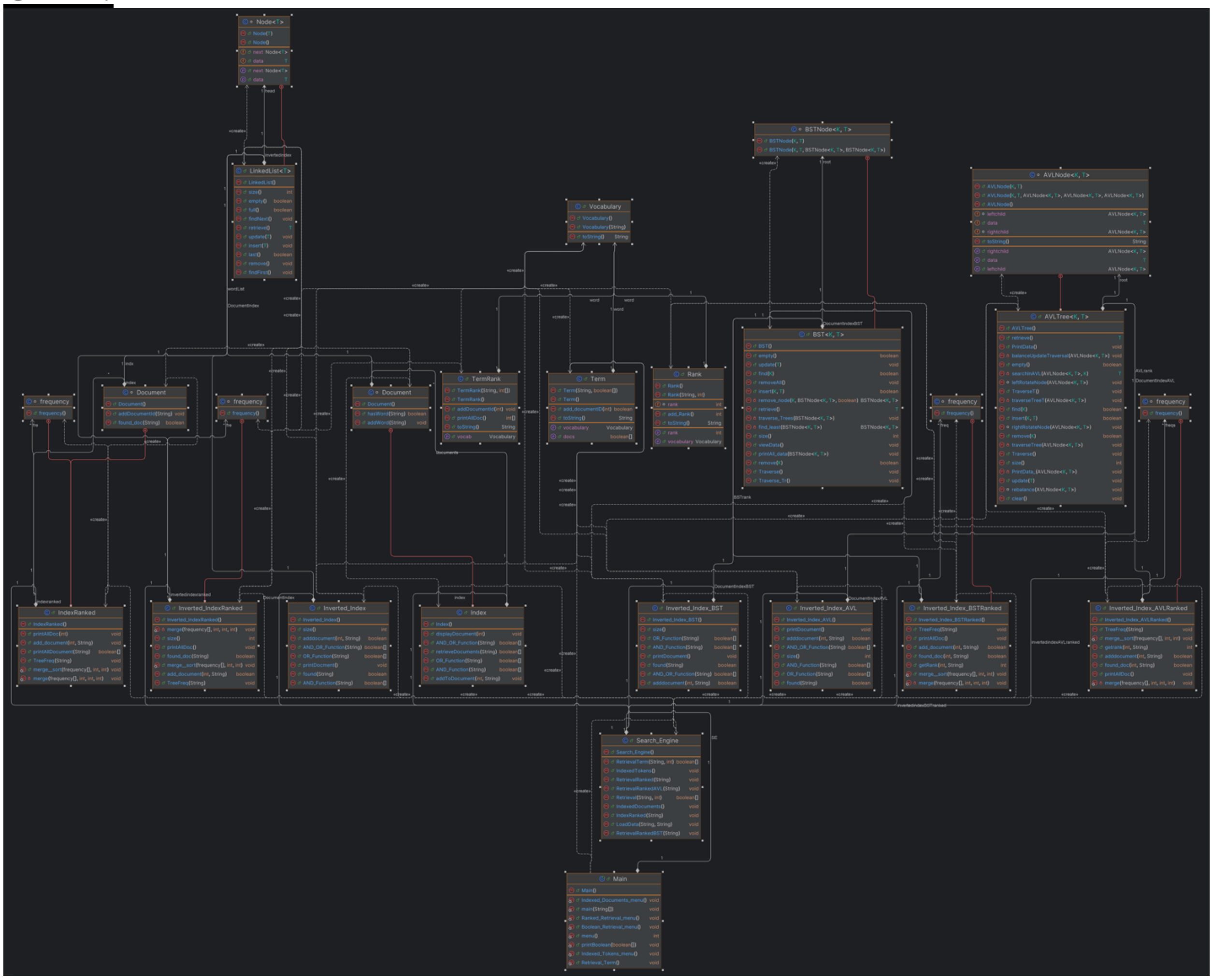
Best Choice

Class Inverted Index BST: is the best solution overall since it is more efficient for large datasets and frequent lookups or updates due to its logarithmic complexity O (log n) for operations.

Our github:

https://github.com/Ft0oo0n6/data-structure-.git

UML:



Node<T>
LinkedList<T>
BSTNode<K, T>
AVLNode<K, T>
Vocabulary
BST<K, T>
AVLTree<K, T>
frequency
Document
frequency
Document
TermRank
Term
Rank
frequency
frequency
IndexRanked
Inverted_IndexRanked
Inverted_Index
Index
Inverted_Index_BST
Inverted_Index_AVL
Inverted_Index_BSTRanked
Inverted_Index_AVLRanked
Search_Engine
Main

Sample run:

```
 ----jGRASP exec: java Main
tokens 1443
vocabs 640
1. Term Retrieval.
2. Boolean Retrieval.
3. Ranked Retrieval.
4. Indexed Documents.
5. Indexed Tokens.
6. Exist.
enter choice
1
------------- Retrieval Term -------------
1. index
2. inverted index
3. inverted index using BST
4. inverted index using AVL
enter your choice
1
Enter Term :
market
Result doc IDs: [ 0, 12, 41]
```

```
1. Term Retrieval.
2. Boolean Retrieval.
3. Ranked Retrieval.
4. Indexed Documents.
5. Indexed Tokens.
6. Exist.
enter choice
2
------------- Boolean Retrieval -------------
1. index
2. inverted index
3. inverted index using BST
4. inverted index using AVL
enter your choice
1
Enter boolean term ( AND / OR) :
market AND sports
Q#: market AND sports
Result doc IDs: Boolean_Retrieval using index list
[ 41]
```

```
1. Term Retrieval.
2. Boolean Retrieval.
3. Ranked Retrieval.
4. Indexed Documents.
5. Indexed Tokens.
6. Exist.
enter choice
3
----- Ranked Retrieval -----
1. index
2. inverted index
3. inverted index using BST
4. inverted index using AVL
enter your choice
1
enter term: market
## Q: market
DocIDt   Score
get ranked from index list

 DocID: t    Score:
0     1
12    1
41    1
```

```
1. Term Retrieval.
2. Boolean Retrieval.
3. Ranked Retrieval.
4. Indexed Documents.
5. Indexed Tokens.
6. Exist.
enter choice
4
-----Indexed Documents -----
Indexed Documents
All Documents with the number of words in them
Document# 0  with size(23)
Document# 1  with size(25)
Document# 2  with size(22)
Document# 3  with size(22)
Document# 4  with size(24)
Document# 5  with size(20)
Document# 6  with size(21)
Document# 7  with size(20)
Document# 8  with size(19)
Document# 9  with size(19)
Document# 10  with size(18)
```

```
1. Term Retrieval.
2. Boolean Retrieval.
3. Ranked Retrieval.
4. Indexed Documents.
5. Indexed Tokens.
6. Exist.
enter choice
5
----- Indexed Tokens -----
tokens
All tokens with the documents appear in it
abilities
the document it's: 33
accelerating
the document it's: 28
accommodate
the document it's: 48
accuracy
the document it's: 49
accurate
the document it's: 30
activities
the document it's: 34
activity
the document it's: 46
adapt
```