Basic and Advanced Ranked Retrieval Techniques using Java

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Author Note

The implementations described in here were done using Java 12 without the use of external libraries. All instructions for running the files are located in the README.

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Abstract

[The abstract should be one paragraph of between 150 and 250 words. It is not indented. Section titles, such as the word Abstract above, are not considered headings so they don’t use bold heading format. Instead, use the Section Title style. This style automatically starts your section on a new page, so you don’t have to add page breaks. To apply any text style in this document with just a tap, have a look at Styles on the Home tab of the ribbon.]

Keywords: Search Engine, Automatic Query Expansion, Okapi BM25

Basic and Advanced Ranked Retrieval Techniques using Java

# Okapi BM25 Ranked Retrieval

Okapi BM25 (BM25) is a probabilistic ranked retrieval function that was developed for use in estimating relevance of documents in a collection with regards to a given search query. The version of BM25 that was implemented in this program was simplified to:

The terms are defined as:

* Q is a query consisting of terms t
* Dd is a document in the collection
* N is the number of documents in the collection
* fd,t is the number of occurrences of t in d
* ft is the number of documents containing term t
* Ld and AL are the document length and average document length, measured as the number of characters in the data file.
* k1 and b are parameters that are initially be set as k1 = 1.2 and b = 0.75

## Implementation

The implementation of BM25 in this program was done using the standard Java *Math Package* (Oracle, n.d.). Reading the supplied equation, an implemented equation was created with the required variables supplied via the arguments. Changes were required to be made to the Indexing files to record the size of each individual document in the mapping file. This was done to correctly implement the BM25 function for each document.

Indexing. The changes to the indexing modules were required to perform the calculation of BM25. Changes included the recording of document content lengths, including the data between the ‘heading’ and ‘text’ tags in the original document collection. These values were recorded together with the mapping information of the raw document identifiers and the uniquely generated identifiers of the indexing program (Chew, 2019).

### **Querying Process.**

Stopping. The process that query terms were subjected to firstly include a stopping of the terms, ensuring the format of the query terms are consistent with the indexed documents. This process employs a method originally created for indexing but has been utilized here in the same fashion for the query terms.

File Handling. Next the lexical and mapping data are read from their respective files into memory of the program. This is done using standard Java IO, similarly done to the indexing portion of the program. The main different in this implementation would be the extra recording of the document weights, as lengths of the document and the averaging of the weights.

Similarity Scoring. After the intake of the required inverted list information, the query processing module is created using the inverted list data. Post-creation, the query terms are then processed one-by-one through the documents and calculations to find all relevant documents for the term and to calculate the partial accumulator scores for the documents. The process in which this has been done is through simply iterating through each term and running the process with the term. Over each term the similarity score is then accrued, run through a min-heap, and finally returned to the main function to be presented to the user.

## **Data Structures and Algorithms.**

Min-Heap. Data structures of interest in this implantation would involve the use of the Priority Queue as an implementation of a min-heap. This was used as a simple method of sorting the data organically without the use of a dedicated sorting function.

Accumulator. Another data structure that is crucial to the functionality of the program is the implementation of the Accumulator (util.Accumulator). In practice this structure is purely a container of data, however to allow the structure to be compatible with the Priority Queue, there needed to be a proper definition of being able to determine which accumulator was of higher value. In this case, this was achieved by extending the Comparable class and overriding the ‘compareTo’ method. This implementation of the accumulator allowed for the internal heapification of the inputted accumulators in the Priority Queue.

Advanced IR Feature

# Automatic Query Expansion

Automatic Query Expansion (AQE) defines a method in which the original query is reformed to a state that includes a higher number of query terms to search. This is a form of pseudo-relevance feedback (Claudio Carpineto, 2012) where it is assumed that documents that are relevant to the query will contain other terms related to the original search query (Olalere A. Abass, 2017).

## Achievement Goals

The aim of this feature is to increase the effectiveness of the Information Retrieval system whereby the returned documents are ranked more effectively so that documents that were initially passed as not relevant that in reality have higher relevancy are returned.

## Implementation

This feature was implemented by building upon the initial BM25 program. The separation of methods was achieved using command line arguments.

Indexing. For this implementation, additional changes were needed to be done to the indexing module of the program. Specifically, locations of document positions in the original collection were needed to be recorded (DocumentHandler: 115, DocumentHandler: 143). This was to allow for AQE to be done with pseudo-relevance feedback, where the document contents are added and processed with the below implementation (Claudio Carpineto, 2012).

Querying Process. The changes to the search function included a second pass of query terms after expansion. The documents were extracted from the read from the original document collection and were stopped. These words are then processed using the TSV calculation:

Using this calculation in a min heap structure, the most relevant terms were selected, the number based on the . After selecting the terms, the new query terms are passed through the ranked searching algorithm again. This time, the new query terms’ similarity score were calculated using the Robert-Sparck Jones score.

Using this measure, the similarity scores are calculated and reduced by a third to reduce the power of the new terms. After which the top accumulators will be selected identical to the basic ranked search, and returned to the user with the original queries.

Evaluation

‘P@10’, precision at 10, is the mean of the precision of the first ten documents retrieved across multiple search queries. Through the investigative analysis, it was found to not be a sensible metric for comparing the two systems because the results did not amount to any statistical significance. This led to there being no valid conclusions that could be drawn from the 5 search queries’ terms’ results. The query results showed a pattern that the relevance of the first query number of the query expansion system is slightly higher than the normal retrieval system, however the remaining 19 answers were identical. The only disparity between the queries was that the ‘osteoporosis’ query relevance scores were consistently higher throughout the entire answer lists. The differences were however only to a small extent in the AQE than the normal retrieval.

Perhaps a more appropriate measure to use for the evaluation of these 2 systems would be either recall or fall-out. This measure can be used to know how well the system takes the relevant documents as the outputs are the same. The argument may be reversed with fall-out and would tell the effectiveness of the system in terms of retrieving documents relevant to the query.

The results were not conclusive enough to be able to determine which approach would be better suited in terms of relevance. However, given the time efficiency of each approach, it can be shown that using this implementation of AQE does not have a higher suitability to gaining more relevant search results. Thus, if given the choice between this implementation of AQE or ranked retrieval, the implementation of basic ranked retrieval would be preferred due to the time efficiency compared with AQE.

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| foreign minorities germany | |
| java Search -BM25 -n 20 -l lexicon -i invlist -m map -s stoplist -q 401 | java Search -BM25 -n 20 -l lexicon -i invlist -m map -s stoplist -q 401 -a 10 25 ./../../../IIDocs/latimes |
| 401 LA101790-0075 1 13.562  401 LA021890-0100 2 13.24  401 LA050690-0109 3 12.442  401 LA100890-0131 4 12.422  401 LA040789-0015 5 12.238  401 LA021490-0049 6 12.127  401 LA031590-0102 7 11.992  401 LA111089-0188 8 11.911  401 LA071890-0073 9 11.911  401 LA020789-0133 10 11.843  401 LA050790-0042 11 11.746  401 LA060890-0011 12 11.731  401 LA082789-0152 13 11.654  401 LA021190-0168 14 11.629  401 LA040590-0157 15 11.463  401 LA050390-0176 16 11.42  401 LA062290-0172 17 11.419  401 LA112189-0066 18 11.413  401 LA030990-0189 19 11.393  401 LA050990-0043 20 11.356  938 ms | 401 LA101790-0075 1 14.389  401 LA021890-0100 2 13.24  401 LA050690-0109 3 12.442  401 LA100890-0131 4 12.422  401 LA040789-0015 5 12.238  401 LA021490-0049 6 12.127  401 LA031590-0102 7 11.992  401 LA111089-0188 8 11.911  401 LA071890-0073 9 11.911  401 LA020789-0133 10 11.843  401 LA050790-0042 11 11.746  401 LA060890-0011 12 11.731  401 LA082789-0152 13 11.654  401 LA021190-0168 14 11.629  401 LA040590-0157 15 11.463  401 LA050390-0176 16 11.42  401 LA062290-0172 17 11.419  401 LA112189-0066 18 11.413  401 LA030990-0189 19 11.393  401 LA050990-0043 20 11.356  6749 ms |

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| behavioral genetics | |
| java Search -BM25 -n 20 -l lexicon -i invlist -m map -s stoplist -q 402 | java Search -BM25 -n 20 -l lexicon -i invlist -m map -s stoplist -q 402 -a 10 25 ./../../../IIDocs/latimes |
| 402 LA101290-0115 1 20.681  402 LA052290-0110 2 14.186  402 LA020389-0077 3 13.465  402 LA121289-0055 4 13.339  402 LA082590-0108 5 12.709  402 LA080190-0099 6 12.303  402 LA042990-0032 7 11.546  402 LA020789-0112 8 11.367  402 LA071689-0143 9 11.222  402 LA110889-0005 10 10.992  402 LA071489-0085 11 10.802  402 LA021290-0061 12 10.715  402 LA042390-0048 13 10.683  402 LA012589-0063 14 10.664  402 LA030289-0084 15 10.594  402 LA060289-0090 16 10.536  402 LA040790-0127 17 10.517  402 LA051689-0102 18 10.453  402 LA020789-0113 19 10.448  402 LA051389-0010 20 10.302  605 ms | 402 LA101290-0115 1 22.751  402 LA052290-0110 2 14.186  402 LA121289-0055 3 13.606  402 LA020389-0077 4 13.465  402 LA080190-0099 5 13.054  402 LA082590-0108 6 12.709  402 LA042990-0032 7 12.116  402 LA020789-0112 8 12.106  402 LA071689-0143 9 11.222  402 LA110889-0005 10 10.992  402 LA071489-0085 11 10.802  402 LA021290-0061 12 10.715  402 LA042390-0048 13 10.683  402 LA012589-0063 14 10.664  402 LA030289-0084 15 10.594  402 LA060289-0090 16 10.536  402 LA040790-0127 17 10.517  402 LA051689-0102 18 10.453  402 LA020789-0113 19 10.448  402 LA051389-0010 20 10.302  9212 ms |

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| osteoporosis | |
| java Search -BM25 -n 20 -l lexicon -i invlist -m map -s stoplist -q 403 | java Search -BM25 -n 20 -l lexicon -i invlist -m map -s stoplist -q 403 -a 10 25 ./../../../IIDocs/latimes |
| 403 LA030689-0082 1 15.842  403 LA071290-0133 2 15.766  403 LA083089-0024 3 15.055  403 LA020490-0136 4 14.897  403 LA011389-0029 5 14.659  403 LA010790-0103 6 14.317  403 LA051490-0120 7 13.201  403 LA032290-0151 8 12.078  403 LA120689-0083 9 11.885  403 LA010390-0067 10 11.741  403 LA111589-0004 11 11.451  403 LA042589-0052 12 11.333  403 LA041990-0072 13 11.132  403 LA042189-0027 14 10.524  403 LA051889-0006 15 10.34  403 LA082390-0094 16 10.077  403 LA052290-0110 17 9.908  403 LA022790-0099 18 9.802  403 LA080289-0067 19 9.481  403 LA012990-0041 20 9.459  663 ms | 403 LA020490-0136 1 18.477  403 LA051490-0120 2 18.32  403 LA010790-0103 3 17.74  403 LA071290-0133 4 17.731  403 LA083089-0024 5 16.108  403 LA011389-0029 6 15.866  403 LA030689-0082 7 15.842  403 LA120689-0083 8 12.819  403 LA111589-0004 9 12.228  403 LA032290-0151 10 12.078  403 LA041990-0072 11 11.863  403 LA010390-0067 12 11.741  403 LA042589-0052 13 11.333  403 LA080289-0067 14 11.078  403 LA042689-0065 15 10.818  403 LA082390-0094 16 10.817  403 LA051889-0006 17 10.747  403 LA042189-0027 18 10.524  403 LA110890-0217 19 10.317  403 LA052290-0110 20 10.116  5499 ms |

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| cosmic events | |
| java Search -BM25 -n 20 -l lexicon -i invlist -m map -s stoplist -q 405 | java Search -BM25 -n 20 -l lexicon -i invlist -m map -s stoplist -q 405 -a 10 25 ./../../../IIDocs/latimes |
| 405 LA012289-0002 1 14.881  405 LA010889-0109 2 12.317  405 LA063089-0071 3 12.083  405 LA031290-0034 4 11.979  405 LA021690-0057 5 11.45  405 LA042089-0083 6 11.264  405 LA020190-0053 7 10.904  405 LA061490-0089 8 10.609  405 LA121690-0039 9 10.528  405 LA122989-0137 10 10.299  405 LA031389-0056 11 10.282  405 LA121589-0173 12 10.219  405 LA111789-0134 13 10.169  405 LA081190-0002 14 10.166  405 LA090190-0129 15 10.047  405 LA100690-0017 16 9.761  405 LA010790-0016 17 9.552  405 LA091789-0029 18 9.513  405 LA050990-0163 19 9.508  405 LA041689-0021 20 9.387  636 ms | 405 LA012289-0002 1 15.307  405 LA010889-0109 2 12.317  405 LA063089-0071 3 12.083  405 LA031290-0034 4 11.979  405 LA021690-0057 5 11.45  405 LA042089-0083 6 11.264  405 LA020190-0053 7 10.904  405 LA061490-0089 8 10.609  405 LA121690-0039 9 10.528  405 LA122989-0137 10 10.299  405 LA031389-0056 11 10.282  405 LA121589-0173 12 10.219  405 LA111789-0134 13 10.169  405 LA081190-0002 14 10.166  405 LA090190-0129 15 10.047  405 LA100690-0017 16 9.761  405 LA010790-0016 17 9.552  405 LA091789-0029 18 9.513  405 LA050990-0163 19 9.508  405 LA041689-0021 20 9.387  6293 ms |

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| tropical storms | |
| java Search -BM25 -n 20 -l lexicon -i invlist -m map -s stoplist -q 408 | java Search -BM25 -n 20 -l lexicon -i invlist -m map -s stoplist -q 408 -a 10 25 ./../../../IIDocs/latimes |
| 408 LA101490-0142 1 20.414  408 LA062290-0070 2 18.515  408 LA101390-0102 3 17.887  408 LA101289-0148 4 17.152  408 LA103190-0052 5 16.399  408 LA091989-0049 6 16.315  408 LA120389-0130 7 16.246  408 LA021690-0167 8 15.744  408 LA030990-0199 9 14.702  408 LA092089-0027 10 12.669  408 LA110390-0071 11 12.118  408 LA082189-0033 12 10.999  408 LA102189-0071 13 10.91  408 LA030989-0189 14 10.901  408 LA051190-0106 15 10.726  408 LA040289-0192 16 10.707  408 LA060689-0099 17 10.656  408 LA020289-0156 18 10.637  408 LA050489-0061 19 10.524  408 LA121490-0119 20 10.413  582 ms | 408 LA101490-0142 1 21.408  408 LA062290-0070 2 18.515  408 LA101390-0102 3 18.057  408 LA101289-0148 4 17.152  408 LA092089-0027 5 17.079  408 LA103190-0052 6 16.963  408 LA120389-0130 7 16.642  408 LA091989-0049 8 16.315  408 LA030990-0199 9 16.08  408 LA021690-0167 10 15.744  408 LA110390-0071 11 12.646  408 LA082189-0033 12 10.999  408 LA102189-0071 13 10.91  408 LA030989-0189 14 10.901  408LA051190-0106 15 10.726  408 LA040289-0192 16 10.707  408 LA060689-0099 17 10.656  408 LA020289-0156 18 10.637  408 LA050489-0061 19 10.524  408 LA121490-0119 20 10.413  9504 ms |

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Footnotes

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