# Analysis of different approaches

BM25 scoring function

The BM25 scoring function does not work well when the keyword searched for is contained in more than half of the corpus documents. In this case, the inverse document frequency function will return a negative value, and a document that does not contain the phrase queried for might be scored higher than a document that contains the query.

However, this behavior can be treated in a number of ways. We implemented one of these fixes, and we fixed it by giving each term in the function a floor of 0.005, to avoid counting very common words.

N-gram

Using n-grams allows us to calculate how often words appear close to each other. Words that often appear close to each other are likely more related to each other than words that do not. However, the size of the collection of n-grams can easily get overwhelming when implementing this. What we did to fix this problem is what was mentioned in the article *Identifying Implicit Relationships*. We used stemming, i.e. reducing words to their word stem, and stop-word removal, i.e. removal of unnecessary words such as “the”, “for”. By doing this, we could reduce our number of n-grams.

Query 1 – “adams”

'adams' 'president' 'john' 'quincy' 'wa'

Query 2 – “Lincoln”

'lincoln' 'president' 'wa' 'lincoln's' 'abraham'

Query 3 – “president”

'president' 'wa' 'vice' 'presidential' 'became'

Query 4 – “assassinated president”

[]

Query 5 – “great president”

[]

Query 6 – “first president”

[]

Query 7 – “civil war president”

[]

Skip bi-gram

Skip bi-grams gives higher credits to passages where the candidate answer appears together with words from the clue. However, one of the major weaknesses is that skip bi-grams do not take into account words that are similar, but not identical.

Passage term matching

Passage term matching checks how often a candidate answer appears in the same passage as words from the clue. One of the two major strengths that come from this is that the order of the words and syntactic structure does not matter. The other one is that passage term matching will take into account passages that do not contain the correct answer, but will help extract information from that passage to support candidate answers extracted from other passages.

However, this second strength mentioned can also be a weakness. By using passages that do not contain the correct answer to support other candidate answers, passages that are closely related to the clue but are not actually correct will be assigned too much credit.

# BM25 SCORING FUNCTION

Query 1

|  |  |
| --- | --- |
| 0.0824992124008572 | 25 |
| 0.0794538704333526 | 27 |
| 0.0210766456939933 | 22 |
| 0.0128955579173646 | 13 |
| 0.00837981554156189 | 36 |
| 0.00803673233826394 | 28 |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |

Query 2

|  |  |
| --- | --- |
| 0.0585564324557654 | 1 |
| 0.0188623212369058 | 37 |
| 0.0138279146965538 | 3 |
| 0.00681608987369571 | 20 |
| 0.00677427698620173 | 19 |
| 0.00673285018208420 | 31 |
| 0.00388652209760521 | 13 |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |

Query 3

|  |  |
| --- | --- |
| 0.000237474038231101 | 4 |
| 0.000157132466136599 | 28 |
| 0.000133502390484170 | 15 |
| 0.000118799497161705 | 8 |
| 0.000117002194757061 | 31 |
| 0.000111849253852882 | 32 |
| 0.000109760650916130 | 13 |
| 9.87743716225431e-05 | 36 |
| 9.21383156070192e-05 | 27 |
| 8.23509935180430e-05 | 37 |

Query 4

|  |  |
| --- | --- |
| 0.0106973229229128 | 29 |
| 0.0105445921358247 | 1 |
| 0.000237474038231101 | 4 |
| 0.000157132466136599 | 28 |
| 0.000133502390484170 | 15 |
| 0.000118799497161705 | 8 |
| 0.000117002194757061 | 31 |
| 0.000111849253852882 | 32 |
| 0.000109760650916130 | 13 |
| 9.87743716225431e-05 | 36 |

Query 5

|  |  |
| --- | --- |
| 0.00478902472828646 | 35 |
| 0.00369251791574913 | 29 |
| 0.00281210535517798 | 10 |
| 0.00277544654369421 | 7 |
| 0.00260357976228817 | 22 |
| 0.00145371433904064 | 38 |
| 0.00143439052640571 | 6 |
| 0.00141982695826946 | 21 |
| 0.00141820743064821 | 19 |
| 0.00141210312915129 | 16 |

Query 6

|  |  |
| --- | --- |
| 0.000317647470101474 | 4 |
| 0.000220463115041372 | 28 |
| 0.000200611957229650 | 15 |
| 0.000154028610526309 | 32 |
| 0.000135027312772853 | 5 |
| 0.000133773961424647 | 8 |
| 0.000131793192974886 | 27 |
| 0.000123298870364250 | 25 |
| 0.000122936778132214 | 42 |
| 0.000117160292952778 | 6 |

Query 7

|  |  |
| --- | --- |
| 0.00428348599578618 | 8 |
| 0.00370436175532328 | 1 |
| 0.00290700964924122 | 5 |
| 0.00282090856505984 | 16 |
| 0.00267662212072603 | 37 |
| 0.00164463317579907 | 28 |
| 0.00154590989633296 | 41 |
| 0.00151186081770390 | 31 |
| 0.00149443028537228 | 3 |
| 0.00147274795254648 | 40 |

Query 8

|  |  |
| --- | --- |
| 0.000239751427820550 | 4 |
| 0.000109396419835634 | 30 |
| 0.000103859290046850 | 10 |
| 7.48882202275899e-05 | 12 |
| 7.33669417737936e-05 | 21 |
| 6.01967583359599e-05 | 5 |
| 5.97904817154892e-05 | 17 |
| 5.92767548421126e-05 | 18 |
| 5.90953020204664e-05 | 40 |
| 5.87349023115662e-05 | 11 |

Query 9, USA

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 | 34 |

Query 10, good

|  |  |
| --- | --- |
| 0.0093 | 22 |
| 0.0055 | 28 |
| 0.0051 | 38 |
| 0.0050 | 10 |
| 0.0050 | 40 |
| 0.0049 | 34 |
| 0.0044 | 1 |
| 0.0043 | 35 |
| 0.0043 | 12 |
| 0.0030 | 13 |

Query 11, president

|  |  |
| --- | --- |
| 0.0099 | 22 |
| 0.0057 | 38 |
| 0.0056 | 10 |
| 0.0055 | 28 |
| 0.0055 | 34 |
| 0.0050 | 40 |
| 0.0049 | 1 |
| 0.0043 | 35 |
| 0.0043 | 12 |
| 0.0036 | 13 |

Query 12, international

|  |  |
| --- | --- |
| 0.0084 | 10 |
| 0.0083 | 21 |
| 0.0083 | 6 |
| 0.0078 | 42 |
| 0.0077 | 33 |
| 0.0001 | 23 |
| 0.0001 | 17 |
| 0.0001 | 25 |
| 0.0001 | 40 |
| 0.0001 | 9 |

Query 13, elected

|  |  |
| --- | --- |
| 0.0001 | 16 |
| 0 | 20 |
| 0 | 4 |
| 0 | 19 |
| 0 | 34 |
| 0 | 14 |
| 0 | 2 |
| 0 | 30 |
| 0 | 27 |
| 0 | 29 |

Query 14, election

|  |  |
| --- | --- |
| 0.0031 | 41 |
| 0.0027 | 42 |
| 0.0022 | 36 |
| 0.0020 | 38 |
| 0.0020 | 5 |
| 0.0019 | 34 |
| 0.0018 | 15 |
| 0.0011 | 13 |
| 0.0010 | 28 |
| 0.0010 | 3 |

Query 15, business

|  |  |
| --- | --- |
| 0.0264 | 33 |
| 0.0121 | 38 |
| 0.0073 | 30 |
| 0.0068 | 13 |
| 0.0042 | 28 |
| 0.0040 | 5 |
| 0.0040 | 16 |
| 0.0040 | 10 |
| 0.0040 | 18 |
| 0.0039 | 7 |

Query 16, economy

|  |  |
| --- | --- |
| 0.0184 | 15 |
| 0.0135 | 18 |
| 0.0072 | 41 |
| 0.0068 | 10 |
| 0.0067 | 7 |
| 0.0063 | 30 |
| 0.0057 | 12 |
| 0 | 43 |
| 0 | 42 |
| 0 | 40 |

Query 17, abolish

|  |  |
| --- | --- |
| 0.0290 | 31 |
| 0.0283 | 43 |
| 0.0196 | 11 |
| 0.0099 | 19 |
| 0.0093 | 22 |
| 0.0053 | 28 |
| 0.0051 | 3 |
| 0.0046 | 23 |
| 0.0046 | 30 |
| 0.0044 | 27 |

# PASSAGE TERM MATCHING

Query 1

|  |  |
| --- | --- |
| 3.30525707202109 | 36 |
| 3.30525707202109 | 28 |
| 3.30525707202109 | 27 |
| 3.30525707202109 | 25 |
| 3.30525707202109 | 22 |
| 3.30525707202109 | 13 |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |

Query 2

|  |  |
| --- | --- |
| 4.16230968473294 | 37 |
| 4.16230968473294 | 31 |
| 4.16230968473294 | 20 |
| 4.16230968473294 | 19 |
| 4.16230968473294 | 13 |
| 4.16230968473294 | 3 |
| 4.16230968473294 | 1 |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |

Query 3

|  |  |
| --- | --- |
| 0 | 34 |
| -1806006467323.23 | 43 |
| -1806006467323.23 | 42 |
| -1806006467323.23 | 41 |
| -1806006467323.23 | 40 |
| -1806006467323.23 | 39 |
| -1806006467323.23 | 38 |
| -1806006467323.23 | 37 |
| -1806006467323.23 | 36 |
| -1806006467323.23 | 35 |

Query 4

|  |  |
| --- | --- |
| 16.5252764828192 | 29 |
| 16.5252764828192 | 1 |
| 15.7741275517990 | 43 |
| 15.7741275517990 | 42 |
| 15.7741275517990 | 41 |
| 15.7741275517990 | 40 |
| 15.7741275517990 | 39 |
| 15.7741275517990 | 38 |
| 15.7741275517990 | 37 |
| 15.7741275517990 | 36 |

Query 5

|  |  |
| --- | --- |
| 73.4608899951204 | 42 |
| 73.4608899951204 | 40 |
| 73.4608899951204 | 38 |
| 73.4608899951204 | 35 |
| 73.4608899951204 | 33 |
| 73.4608899951204 | 30 |
| 73.4608899951204 | 29 |
| 73.4608899951204 | 27 |
| 73.4608899951204 | 25 |
| 73.4608899951204 | 23 |

Query 6

|  |  |
| --- | --- |
| 160.840808430583 | 42 |
| 160.840808430583 | 39 |
| 160.840808430583 | 35 |
| 160.840808430583 | 33 |
| 160.840808430583 | 32 |
| 160.840808430583 | 29 |
| 160.840808430583 | 28 |
| 160.840808430583 | 27 |
| 160.840808430583 | 26 |
| 160.840808430583 | 25 |

Query 7

|  |  |
| --- | --- |
| 99.2716624731154 | 42 |
| 99.2716624731154 | 41 |
| 99.2716624731154 | 40 |
| 99.2716624731154 | 37 |
| 99.2716624731154 | 31 |
| 99.2716624731154 | 29 |
| 99.2716624731154 | 28 |
| 99.2716624731154 | 26 |
| 99.2716624731154 | 23 |
| 99.2716624731154 | 16 |

Query 8

|  |  |
| --- | --- |
| 41.7603098606995 | 41 |
| 41.7603098606995 | 40 |
| 41.7603098606995 | 35 |
| 41.7603098606995 | 30 |
| 41.7603098606995 | 27 |
| 41.7603098606995 | 25 |
| 41.7603098606995 | 23 |
| 41.7603098606995 | 22 |
| 41.7603098606995 | 21 |
| 41.7603098606995 | 20 |

Query 9, USA

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 | 34 |

Query 10, good president

|  |  |
| --- | --- |
| 38.1426 | 40 |
| 38.1426 | 38 |
| 38.1426 | 35 |
| 38.1426 | 28 |
| 38.1426 | 22 |
| 38.1426 | 13 |
| 38.1426 | 12 |
| 38.1426 | 10 |
| 38.1426 | 1 |
| 30.8075 | 43 |

Query 11, president who is good

|  |  |
| --- | --- |
| 41.3937 | 22 |
| 41.3937 | 1 |
| 37.2953 | 41 |
| 37.2953 | 23 |
| 37.2953 | 21 |
| 37.2953 | 20 |
| 37.2953 | 16 |
| 37.2953 | 14 |
| 37.2953 | 7 |
| 37.2953 | 6 |

Query 12, international war

|  |  |
| --- | --- |
| 19.3422 | 42 |
| 19.3422 | 33 |
| 19.3422 | 21 |
| 19.3422 | 10 |
| 16.9834 | 43 |
| 16.9834 | 41 |
| 16.9834 | 40 |
| 16.9834 | 39 |
| 16.9834 | 37 |
| 16.9834 | 36 |

Query 13, elected 1982

|  |  |
| --- | --- |
| 7.3378 | 40 |
| 7.3378 | 38 |
| 7.3378 | 37 |
| 7.3378 | 34 |
| 7.3378 | 33 |
| 7.3378 | 32 |
| 7.3378 | 31 |
| 7.3378 | 30 |
| 7.3378 | 29 |
| 7.3378 | 28 |

Query 14, election 1982

|  |  |
| --- | --- |
| 4.1973 | 43 |
| 4.1973 | 42 |
| 4.1973 | 41 |
| 4.1973 | 38 |
| 4.1973 | 36 |
| 4.1973 | 34 |
| 4.1973 | 32 |
| 4.1973 | 28 |
| 4.1973 | 27 |
| 4.1973 | 25 |
|  |  |

Query 15, business growth

|  |  |
| --- | --- |
| 2.8141 | 42 |
| 2.8141 | 38 |
| 2.8141 | 37 |
| 2.8141 | 30 |
| 2.8141 | 28 |
| 2.8141 | 18 |
| 2.8141 | 16 |
| 2.8141 | 15 |
| 2.8141 | 13 |
| 2.8141 | 10 |

Query 16, economy

|  |  |
| --- | --- |
| 4.1623 | 41 |
| 4.1623 | 30 |
| 4.1623 | 18 |
| 4.1623 | 15 |
| 4.1623 | 12 |
| 4.1623 | 10 |
| 4.1623 | 7 |
| 0 | 43 |
| 0 | 42 |
| 0 | 40 |

Query 17, abolish slavery

|  |  |
| --- | --- |
| 2.4823 | 31 |
| 2.2566 | 43 |
| 2.2566 | 30 |
| 2.2566 | 28 |
| 2.2566 | 27 |
| 2.2566 | 23 |
| 2.2566 | 22 |
| 2.2566 | 19 |
| 2.2566 | 11 |
| 2.2566 | 3 |

# SKIP BI-GRAM

Query 1

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 | 34 |

Query 2

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 | 34 |

Query 3

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 | 34 |

Query 4

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 | 34 |

Query 5

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 | 34 |

Query 6

|  |  |
| --- | --- |
| 0.00183486238532110 | 28 |
| 0.00175438596491228 | 6 |
| 0.00173310225303293 | 14 |
| 0.00168918918918919 | 39 |
| 0.00168634064080944 | 42 |
| 0.00166944908180300 | 15 |
| 0.00165289256198347 | 27 |
| 0.00164473684210526 | 29 |
| 0 | 43 |
| 0 | 41 |

Query 7

|  |  |
| --- | --- |
| 0.00351493848857645 | 40 |
| 0.00183150183150183 | 28 |
| 0.00177619893428064 | 5 |
| 0.00176991150442478 | 8 |
| 0.00176678445229682 | 16 |
| 0.00176056338028169 | 18 |
| 0.00175438596491228 | 31 |
| 0.00175131348511384 | 11 |
| 0.00174520069808028 | 34 |
| 0.00168918918918919 | 37 |

Query 8

|  |  |
| --- | --- |
| 0.00319488817891374 | 4 |
| 0.00183150183150183 | 41 |
| 0.00177935943060498 | 5 |
| 0.00177304964539007 | 17 |
| 0.00176991150442478 | 20 |
| 0.00176991150442478 | 16 |
| 0.00176678445229682 | 10 |
| 0.00176366843033510 | 18 |
| 0.00176056338028169 | 40 |
| 0.00175438596491228 | 21 |

Query 9, USA

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 34 | |

Query 10, good president

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 | 34 |

Query 11, president who is good

|  |  |
| --- | --- |
| 0.0018 | 20 |
| 0.0018 | 19 |
| 0.0017 | 25 |
| 0.0017 | 23 |
| 0.0016 | 27 |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |

Query 12, international war

|  |  |  |
| --- | --- | --- |
| 0.0017 | | 33 |
| 0 | 43 | |
| 0 | 42 | |
| 0 | 41 | |
| 0 | 40 | |
| 0 | 39 | |
| 0 | 38 | |
| 0 | 37 | |
| 0 | 36 | |
| 0 | 35 | |

Query 13, elected 1982

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 | 34 |

Query 14, election 1982

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 | 34 |

Query 15, business growth

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 | 34 |

Query 16, economy

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 | 34 |

Query 17, abolish slavery

|  |  |
| --- | --- |
| 0 | 43 |
| 0 | 42 |
| 0 | 41 |
| 0 | 40 |
| 0 | 39 |
| 0 | 38 |
| 0 | 37 |
| 0 | 36 |
| 0 | 35 |
| 0 | 34 |