Fusion: Rank-Based

COMP3009J: Information Retrieval

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Rank-Based Fusion: Interleaving

- **Interleaving** is perhaps the simplest fusion algorithm of all*
- Here, we take one document from the top of each input set in a "**round robin**" fashion and add it to the fused result set.
  - The document chosen is the highest-ranked document that is not yet included in the fused result set.
- The effectiveness of this technique is, however, poor.
- There is an assumption that every result set is of equal quality, which can have the result that the better result sets are diluted by being merged with non-relevant documents from poorer systems.

* Voorhees, E. M., Gupta, N. K., & Johnson-Laird, B. (1994). The Collection Fusion Problem. In *Proceedings of the Third Text REtrieval Conference (TREC-3)* (pp. 95–104)

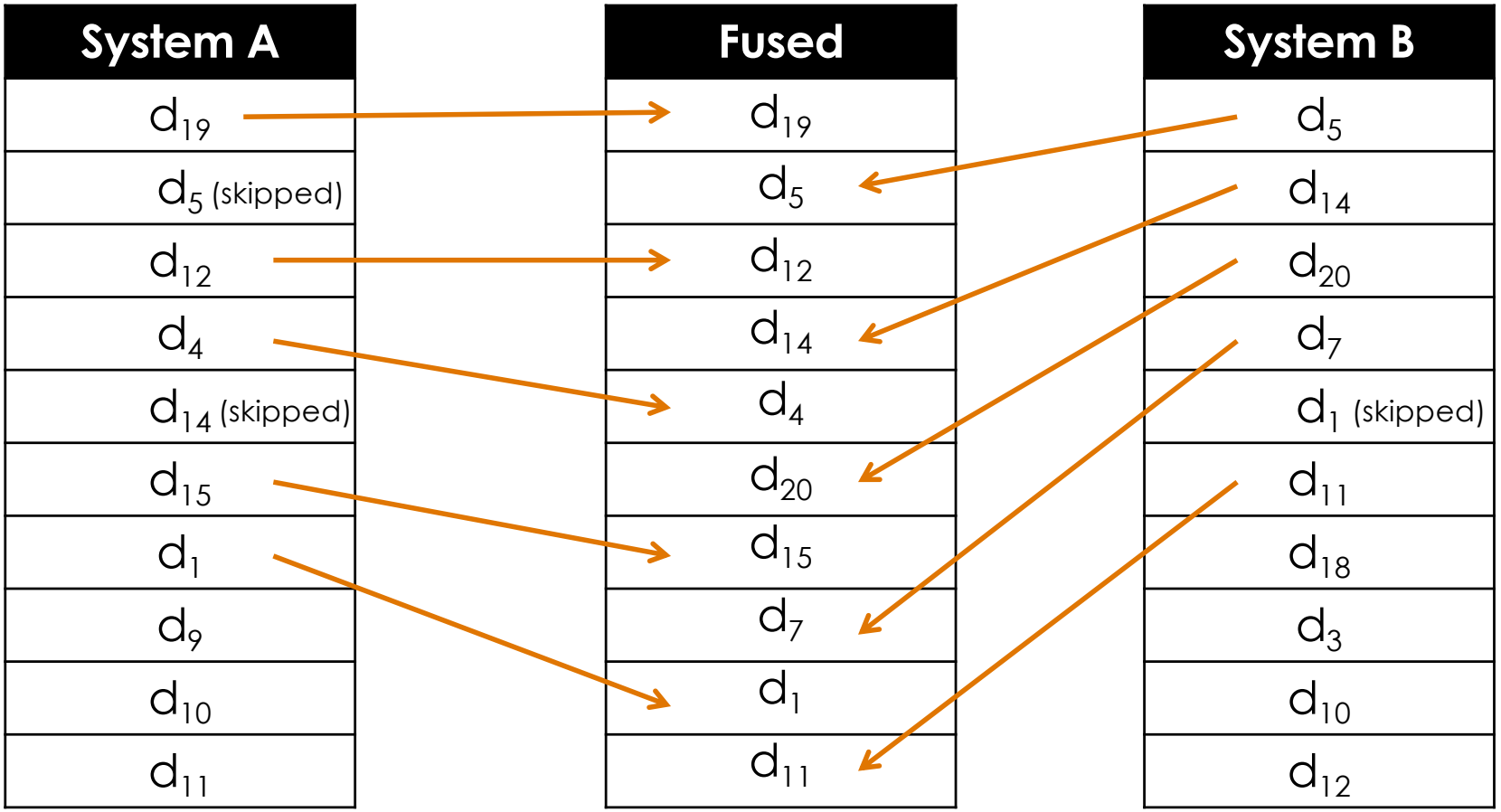
Rank-Based: Interleaving (Example)

System A
d_{19}
d_5
d_{12}
d_4
d_{14}
d_{15}
d_1
d_9
d_{10}
d_{11}

Fused

System B
d_5
d_{14}
d_{20}
d_7
d_1
d_{11}
d_{18}
d_3
d_{10}
d_{12}

Rank-Based: Interleaving (Example)



Rank-Based: Borda-Fuse

- **Borda-Fuse** is based on an election system for when a few voters(input systems) vote for many candidates (documents).
  - Each voter ranks a set of *c* candidates in order of preference.
  - For each voter, the top-ranked candidate is given *c* points, the second ranked is given *c-1* points, etc.
  - If a candidate is not ranked by a voter, the voter's remaining points are divided evenly among unranked candidates.

* Aslam, J. A., & Montague, M. (2001). Models for metasearch. In *SIGIR '01: Proceedings of the 24th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval* (pp. 276–284). New York, NY, USA.

Rank-Based: Borda-Fuse

- **Borda-Fuse** is based on an election system for when a few voters(input systems) vote for many candidates

Inventor: Jean-Charles de Borda
Born 4th May, 1773
French Mathematician, Physicist, Naval Officer
There is a moon crater named after him

Developed "Borda Count" in 1770 to elect members to the French Academy of Science.

Fought in the American Revolution
Helped to define the standard metre
Developed a technique for computing longitude in 1778

* Aslam, J. A., & Montague, M. (2001). Models for metasearch. In *SIGIR '01: Proceedings of the 24th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval* (pp. 276–284). New York, NY, USA.

Rank-Based: Borda-Fuse

System A	Points
d_{19}	14
d_5	13
d_{12}	12
d_4	11
d_{14}	10
d_{15}	9
d_1	8
d_9	7
d_{10}	6
d_{11}	5

System B	Points
d_5	14
d_{14}	13
d_{20}	12
d_7	11
d_1	10
d_{11}	9
d_{18}	8
d_3	7

- 14 unique documents: c = 14
- System A gives 2.5 points to any documents it didn't choose: (4+3+2+1)/4.
- System B gives 3.5 points to documents it didn't choose: (6+5+4+3+2+1)/6

Rank-Based: Borda-Fuse

System A	Points
d_{19}	14
d_5	13
d_{12}	12
d_4	11
d_{14}	10
d_{15}	9
d_1	8
d_9	7
d_{10}	6
d_{11}	5

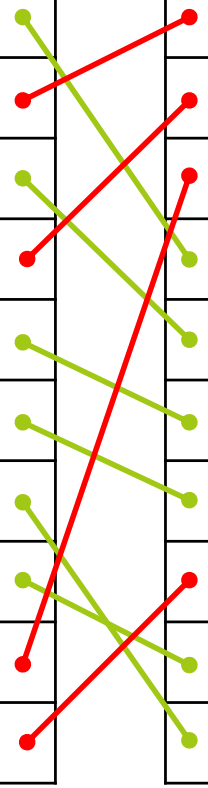
System B	Points
d_5	14
d_{14}	13
d_{20}	12
d_7	11
d_1	10
d_{11}	9
d_{18}	8
d_3	7

Fused	Points (A)	Points (B)	Points (Borda)
d_5	**13**	**14**	27
d_{14}	**10**	**13**	23
d_1	**8**	**10**	18
d_{19}	**14**	3.5	17.5
d_{12}	**12**	3.5	15.5
d_4	**11**	3.5	14.5
d_{20}	2.5	**12**	14.5
d_{11}	**5**	**9**	14
d_7	2.5	**11**	13.5
d_{15}	**9**	3.5	12.5
d_{18}	2.5	**8**	10.5
d_9	**7**	3.5	10.5
d_{10}	**6**	3.5	9.5
d_3	2.5	**7**	9.5

Comparison

System A	System B
d_{19}	d_5
d_5	d_{14}
d_{12}	d_{20}
d_4	d_7
d_{14}	d_1
d_{15}	d_{11}
d_1	d_{18}
d_9	d_3
d_{10}	d_{10}
d_{11}	d_{12}

Interleaving	Borda Fuse
d_{19}	d_5
d_5	d_{14}
d_{12}	d_1
d_{14}	d_{19}
d_4	d_{12}
d_{20}	d_4
d_{15}	d_{20}
d_7	d_{11}
d_1	d_7
d_{11}	d_{15}



Reciprocal Rank Fusion

- Reciprocal Rank Fusion is a simple rank-based method that has been shown to be effective in practice*.
- Given a set of documents *D* to be ranked, and a set of results *R*, the score for each document is calculated as follows:
  - $RRFscore(d \in D) = \sum_{r \in R} \frac{1}{k+r(d)}$
  - where *r(d)* is the rank of document *d* in result set *r*, and *k*=60 (set by experiment)

* Cormack, G. V., Clarke, C. L. A., Büttcher, S. (2009). Reciprocal Rank Fusion outperforms Condorcet and Individual Rank Learning Models. In *Proceedings of the 32nd international ACM SIGIR Conference on Research and Development in Information Retrieval* (pp. 758-759)

Useful Maths

- RRF uses k=60.
- If a document, d, is not ranked, it does not contribute to the RRF Score
  - i. e. the score for the term related to document d in the summation is 0.

Rank	Calculation	RRF Score
1	1/61	0.01639
2	1/62	0.01612
3	1/63	0.01587
4	1/64	0.01562
5	1/65	0.01538
6	1/66	0.01515
7	1/67	0.01492
8	1/68	0.01470
9	1/69	0.01449
10	1/70	0.01428
Not Ranked	0	0.0

Rank-Based: RRF

System A	System B
d_{19}	d_5
d_5	d_{14}
d_{12}	d_{20}
d_4	d_7
d_{14}	**d_1**
d_{15}	d_{11}
d_1	d_{18}
d_9	d_3
d_{10}	d_{10}
d_{11}	d_{12}

$$RRFscore(d_1) = \sum_{r \in R} \frac{1}{k+r(d)} = \frac{1}{67} + \frac{1}{65} = 0.0303$$

Rank-Based: RRF

System A	System B
d_{19}	d_5
d_5	d_{14}
d_{12}	d_{20}
d_4	d_7
d_{14}	d_1
d_{15}	d_{11}
d_1	d_{18}
d_9	**d_3**
d_{10}	d_{10}
d_{11}	d_{12}

$$RRFscore(d_1) = \sum_{r \in R} \frac{1}{k+r(d)} = \frac{1}{67} + \frac{1}{65} = 0.0303$$

$$RRFscore(d_3) = \sum_{r \in R} \frac{1}{k+r(d)} = 0 + \frac{1}{68} = 0.0147$$

Rank-Based: RRF

System A	System B
d_{19}	d_5
d_5	d_{14}
d_{12}	d_{20}
d_4	d_7
d_{14}	d_1
d_{15}	d_{11}
d_1	d_{18}
d_9	d_3
d_{10}	d_{10}
d_{11}	d_{12}

Fused	RRF(A)	RRF(B)	RRF
d_1	0.01492	0.01538	0.0303
d_3		0.01470	0.0147
d_4	0.01562		0.0156
d_5	0.01612	0.01639	0.0325
d_7		0.01562	0.0156
d_9	0.01470		0.0147
d_{10}	0.01449	0.01449	0.0290
d_{11}	0.01428	0.01515	0.0294
d_{12}	0.01587	0.01428	0.0302
d_{14}	0.01538	0.01612	0.0315
d_{15}	0.01515		0.0152
d_{18}		0.01492	0.0149
d_{19}	0.01639		0.0164
d_{20}		0.01587	0.0159

Rank-Based: RRF

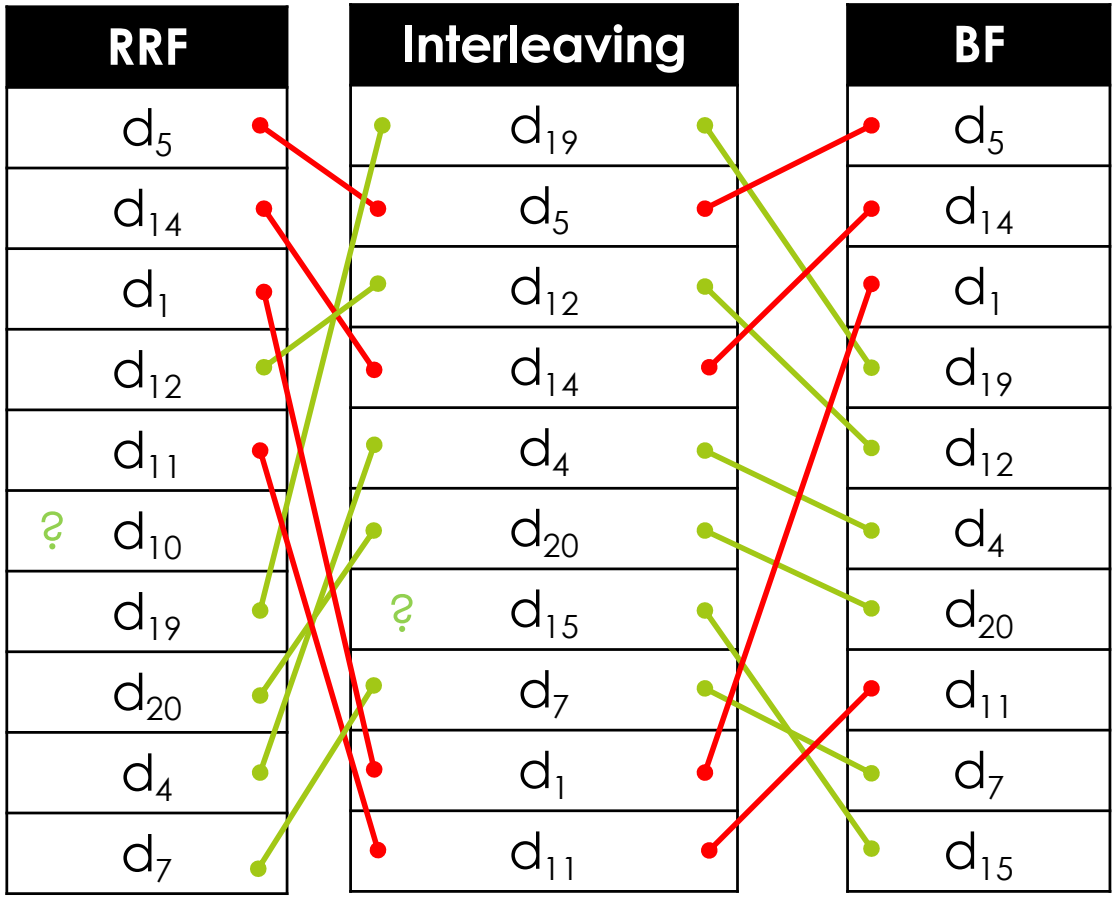
System A	System B
d_{19}	d_5
d_5	d_{14}
d_{12}	d_{20}
d_4	d_7
d_{14}	d_1
d_{15}	d_{11}
d_1	d_{18}
d_9	d_3
d_{10}	d_{10}
d_{11}	d_{12}

Fused	RRF(A)	RRF(B)	RRF
d_5	0.01612	0.01639	0.0325
d_{14}	0.01538	0.01612	0.0315
d_1	0.01492	0.01538	0.0303
d_{12}	0.01587	0.01428	0.0302
d_{11}	0.01428	0.01515	0.0294
d_{10}	0.01449	0.01449	0.0290
d_{19}	0.01639		0.0164
d_{20}		0.01587	0.0159
d_4	0.01562		0.0156
d_7		0.01562	0.0156
d_{15}	0.01515		0.0152
d_{18}		0.01492	0.0149
d_9	0.01470		0.0147
d_3		0.01470	0.0147

Comparison

System A
d_{19}
d_5
d_{12}
d_4
d_{14}
d_{15}
d_1
d_9
d_{10}
d_{11}

System B
d_5
d_{14}
d_{20}
d_7
d_1
d_{11}
d_{18}
d_3
d_{10}
d_{12}



Other Rank-Based Techniques

- A variation on interleaving is to use **historical data** to estimate which input system(s) tends to perform better.
- A weighted version of interleaving is then used so that **more documents are taken from the better systems**. *
- Another election-based approach from the same authors as Borda-Fuse is the *Condorcet-Fuse*** algorithm. A weighted version of Borda-Fuse is also proposed, where the points from each input system are multiplied by some weight.

* Voorhees et al. (1994)

** Montague, M., & Aslam, J. A. (2002). Condorcet fusion for improved retrieval. In *CIKM ' 02: Proceedings of the eleventh international conference on Information and knowledge management* (pp. 538–548). New York, NY, USA.

Class Question 1

System A
d_{10}
d_{18}
d_4
d_6
d_5
d_{17}
d_{11}
d_{14}

System B
d_{18}
d_6
d_1
d_2
d_{17}

System C
d_6
d_4
d_3
d_{18}
d_5
d_{10}
d_{15}
d_{19}

- What is the fused ranking using:
  1. Interleaving?
  2. Borda Fuse?
  3. Reciprocal Rank Fusion?