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# CondorcetFuse

## Condoret voting for run fusion

Evaluation and comparison of an implementation with other fusion strategies

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# 1 Introduction

In Information Retrieval, data fusion is the combination of the results of independent searches on a document collection into one single output result set.

It has been shown in the past that this can greatly improve retrieval effectiveness over that of the individual results.

The aim of this work is to show a possible implementation of some basic fusion strategies and compare them to an advanced one: Condorcet fusion [3].

In this project the input documents were taken from the TREC TIPSTER Collection using 50 topics (topics 351-400). We used Terrier for retrieval and indexing and MATTERS for evaluation.

We organized our work as follows:

- **Indexing:** we created four different indexes:
  - Without both stemmer and stop list;
  - only using the Porter stemmer;
  - only using the stop list;
  - using both the Porter stemmer and the stop list;
- **Retrieval:** 10 different retrieval models listed in Table 1;
- **Normalization:** min/max normalization as presented by Lee [1]
- **Fusion strategy:** we compared seven different fusion strategies:
  - 6 basic strategies proposed by Fox and Shawn [2] and listed in Table 2;
  - Condorcet fusion (advanced strategy) as proposed by Montague and Aslam [3]

Retrieval models	Basic fusion methods	New score formula
BB2	CombMNZ	$(\sum_i^N s_i) * (Num\ s_i \neq 0)$
BM25		
DLH13	CombSUM	$\sum_i^N s_i$
Hiemstra_LM		
IFB2	CombMIN	$min_i^N(s_i)$
TF_IDF		
DFIC	CombMAX	$max_i^N(s_i)$
DFIZ		
DirichletLM	CombMED	$median_i^N(s_i)$
InL2		
	CombANZ	$(\sum_i^N s_i) / (Num\ s_i \neq 0)$

Table 1: Retrieval models used

Table 2: Basic fusion methods used

## 2 Condorcet fusion

The Condorcet Fusion strategy considers the ranking of documents from different systems as an instance of the voting problem where documents are candidates and each input retrieval system is a voter.

The output of each input system is seen as a list of preferences, where the higher ranked document beats the lower ranked ones.

Having the lists of different preferences, Condorcet Fusion orders the documents using the Condorcet voting algorithm, a majoritarian method which specifies that the “winner” of the fusion is the document(s) that beats or ties with every other document in a pair-wise comparison between the input systems (i.e. runs).

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## 2.1 The Condorcet Graph

The Condorcet Graph is used to determine the Condorcet winner.

Given 10 models of retrieval with  $n$  documents, the corresponding Condorcet graph  $G = (V, E)$  has one vertex for each of the  $n$  documents.

For each document pair  $(x, y)$ , there exists an edge from  $x$  to  $y$  (denoted by  $x \rightarrow y$ ) if  $x$  would receive at least as many votes as  $y$  in a head-to-head contest.

Cycles can simply be viewed as ties.

## 2.2 Condorcet paths

A Condorcet-consistent hamiltonian path (or condorcet path) is any hamiltonian path through the Condorcet graph.

The goal of Condorcet Fusion is to efficiently find such a path and to output the documents in the order they are visited as nodes of the path.

## 3 Implementation

We follow the Condorcet Fuse implementation suggested by Montague and Aslam [3].

We choose to assign some dummy relevance score to Condorcet's output, the score is assigned based on the rank.

The implementation of Condorcet uses Quicksort, with the following algorithm as comparing function:

```
count = 0
for each of the k search systems do:
    if sys i ranks d1 above d2, count++
    if sys i ranks d2 above d1, count--
    if count > 0, rank d1 better than d2
    else rank d2 better than d1
```

For more information on the code, see [README](#) in repository.

## 4 Evaluation

The evaluation criteria based on the given pool uses a binary relevance score: Relevant and Non-Relevant. The documents left out from the pool are considered to be Non-Relevant. We decided to use Average Precision to evaluate a run on the set of topics and Mean Average Precision to evaluate between topics. We always work on normalized data.

We first did an analysis considering the 10 models presented in Table 1 running retrieval and indexing with Terrier's default settings (that is, using both the Porter Stemmer and a stop list) and the fusion's given these 10 input systems.

Then, since the paper on Condorcet Fuse performed some analysis to understand the relation between CondFuse's MAP and the number of input systems, we also tried something similar.

### 4.1 First Analysis

At first, we wanted to see if using a fusion strategy actually improves the best performance of a simple model run with both the stemmer (we used Porter Stemmer) and a stop list. We proceeded as follows:

1. We computed the AP and the MAP for the 10 input models;
2. We computed the AP and the MAP for the 7 fusion models (6 basic and Condorcet);
3. We selected the 5 systems with the best MAP values.

Figure 1 shows the Average Precision for the top 5 best systems, while Table 3 shows the MAP for all of them.

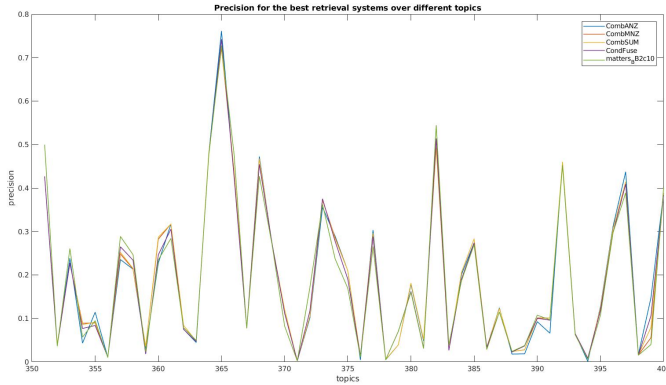


Figure 1: AP over 50 topics for the 5 best systems

Systems	MAP
CombSUM	0.1909
CombMNZ	0.1902
CombANZ	0.1891
CondFuse	0.1883
BB2	0.1881
IFB2	0.1880
DirichletLM	0.1862
InL2	0.1853
CombMED	0.1840
DLH13	0.1829
BM25	0.1827
TF_IDF	0.1821
CombMAX	0.1817
DFIZ	0.1783
DFIC	0.1758
Hiemstra_LM	0.1733
CombMIN	0.1515

Table 3: Retrieval systems sorted by decreasing MAP

#### 4.1.1 Results Analysis

The results of these first tests show that it is generally convenient to use a fusion method. Four out of the top five best systems were fusion systems, with Condorcet Fuse being the fourth best overall.

But, we also noted that the performances of the methods are all very close, and the best and worse topics are the same regardless of the system used.

## 4.2 Further Analysis

We decided we wanted to test how the performances of the 10 input systems affected the performance of the fusion methods. Furthermore, since Montague and Aslan [3] analyzed the algorithm's performance over the number of input systems, we also tried fusions starting with 2 input systems up to 10.

#### 4.2.1 Analysis over increasing number of inputs

Figure 2 shows a comparison between the MAP for the 7 fusion methods over the number of input systems and with different indexing and retrieval settings.

We noted that the number of input system doesn't much affect the performances of the fusion methods. The main difference was given by the indexing and retrieval settings. In particular, having neither the stemmer or the stoplist was similar to having just the stop list, while having both stemmer and stoplist was more similar to just having the stemmer.

We expected the stop list to be more defining than the stemmer, so we performed some further analysis focusing on what affected more the fusions.

#### 4.2.2 Analysis on the indexing and retrieval settings

We wanted to see how the indexing and retrieval settings affect the fusions' performances. Furthermore, we wanted to understand the relationship between the models' and the fusions' performances. Since generally the best fusions were the ones performed over 10 input systems, we just focused on them.

Figure 3 shows the MAP's values for the 10 models over different indexing and retrieval settings, while Figure 4 shows the performance of the fusion method of over the same 10 models with the same settings. CombMIN is not in the graph because of its poor performances and to have a better comparison between the 2 Figures.

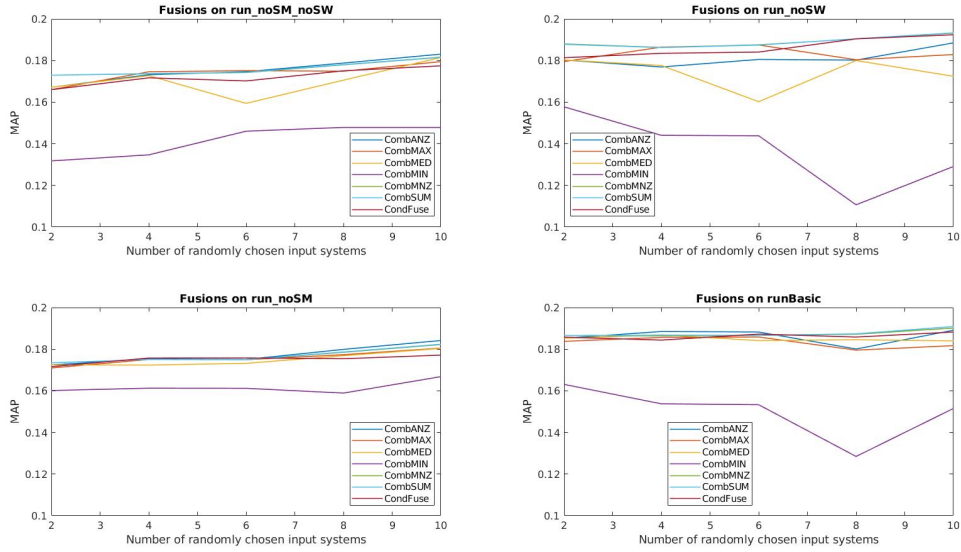


Figure 2: MAP depending in the number of input system and indexing and retrieval settings

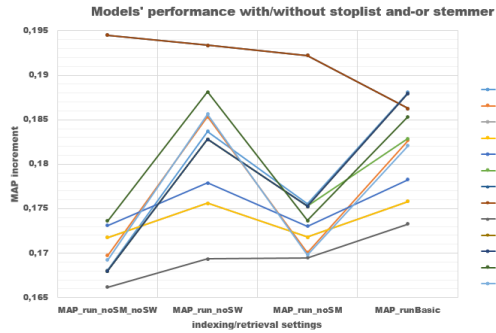


Figure 3: MAP for the retrieval models over different indexing and retrieval settings

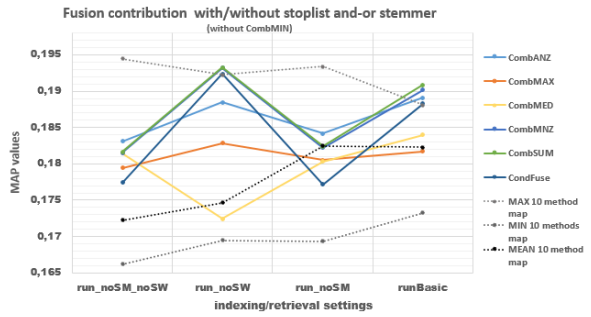


Figure 4: MAP for the fusions over different indexing and retrieval settings

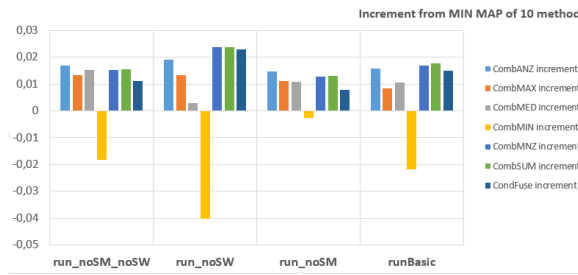
The fusions' performances strongly depend on the input systems' performances. Both in the 10 models and in the fusions the best settings were achieved without the stoplist and with both stoplist and stemmer. This lead us to conclude that, in our collection and with the models selected, the stoplist doesn't really affect the performance.

Still, even though the fusions' performance may seem very similar to the models' one, the maximum and minimum MAP values are higher, and we noted a smaller variance between methods.

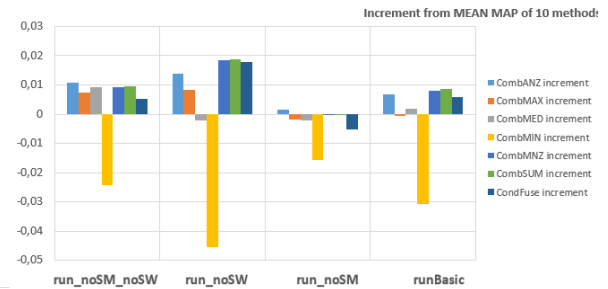
#### 4.2.3 Analysis on the performance's improvement using fusions

Finally, we focused on the improvement a fusion method can bring given a set of input models.

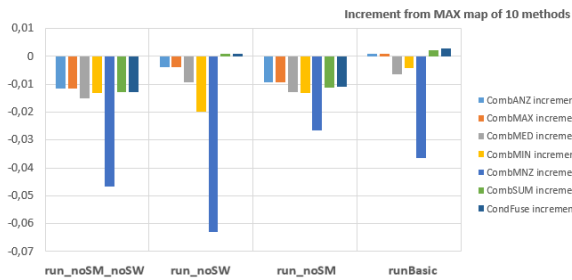
Figures 4.2.3, 4.2.3 and 4.2.3 show how, over different retrieval and indexing settings, the fusion methods improve compared to the respective MIN, MEAN and MAX models' MAP.



Increment of the MIN MAP value compared to the MIN of the input models over different indexing and retrieval settings



Increment of the MEAN MAP value compared to the MEAN of the input models over different indexing and retrieval settings



Increment of the MAX MAP value compared to the MAX of the input models over different indexing and retrieval settings

These results show how there is always at least one fusion method that outperforms the "basic" models, even if the improvement is usually quite small. Condorcet ranks above the majority of fusion methods, bringing the biggest improvement when the input models are obtained with just the stemmer or with both the stemmer and the stop list.

## 5 Conclusions

We implemented and tested different fusion methods. Our evaluation shows that, even if small, fusion methods actually improve the performance of the single models.

But, the improvement isn't very big and it strongly depends on the performance of the input models, that is if the input models already have a good performance, the fusion will be better.

Some fusion methods are clearly worse than others (like CombMIN), being always outperformed, while CondFuse is usually quite good, being one of the top fusion methods tested.

## References

- [1] Lee, Joon Ho. "Combining multiple evidence from different properties of weighting schemes." Proceedings of the 18th annual international ACM SIGIR conference on Research and development in information retrieval. ACM, 1995.
- [2] Fox, Edward A., and Joseph A. Shaw. "Combination of multiple searches." NIST special publication SP 243 (1994).
- [3] Montague, Mark, and Javed A. Aslam. "Condorcet fusion for improved retrieval." Proceedings of the eleventh international conference on Information and knowledge management. ACM, 2002.