

A Comparison of Time-aware Ranking Methods

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ABSTRACT

When searching a temporal document collection, e.g., news archives or blogs, the time dimension must be explicitly incorporated into a retrieval model in order to improve relevance ranking. Previous work has followed one of two main approaches: 1) a mixture model linearly combining textual similarity and temporal similarity, or 2) a probabilistic model generating a query from the textual and temporal part of a document independently. In this paper, we compare the effectiveness of different time-aware ranking methods by using a mixture model applied to all methods. Extensive evaluation is conducted using the New York Times Annotated Corpus, queries and relevance judgments obtained using the Amazon Mechanical Turk.

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1. INTRODUCTION

We deal with a retrieval task that a query is explicitly provided with time, i.e., containing temporal information needs. In this case, the time dimension must be incorporated into a retrieval model in order to improve relevance ranking. Consider a query containing the temporal expression “Independence Day 2009”, an existing retrieval model relying on term matching will fail to retrieve a document mentioning “July 4, 2009”, although two temporal expressions refer to the same date. Hence, when dealing with the time dimension, *time uncertainty* should be taken into account because any two temporal expressions can be *relevant* even they are not equally written.

The previous time-aware ranking methods [1, 2, 3, 4, 5] are based on two main approaches: 1) a mixture model linearly combining textual and temporal similarity, or 2) a probabilistic model generating a query from the textual and temporal part of a document independently. It is shown that time-aware ranking performs better than keyword-based ranking. To the best of our knowledge, an empirical comparison of different time-aware ranking methods has never been done before. In this paper, we will evaluate the effectiveness of different time-aware ranking methods: LMT [1], LMTU [1], TS [4], TSU [4], and FuzzySet [3] using the same dataset, and we will give a brief discussion of the evaluation.

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2. MODEL

A temporal expression or the publication date of a document is represented as a quadruple [1]: (tb_l, tb_u, te_l, te_u) where tb_l and tb_u are the lower bound and upper bound for the begin boundary of a time interval respectively. Similarly, te_l and te_u are the lower bound and upper bound for the end boundary of a time interval. A temporal query q is composed of keywords q_{text} and temporal expressions q_{time} . A document d consists of the textual part d_{text} , i.e., a bag of words, and the temporal part d_{time} composed of the publication date $PubTime(d)$, and temporal expressions mentioned in the document’s contents $ContentTime(d)$ or $\{t_1, \dots, t_k\}$.

To be comparable, we apply a mixture model to linearly combine textual similarity and temporal similarity for all ranking methods. Given a temporal query q , a document d will be ranked according to a score computed as follows:

$$S(q, d) = (1 - \alpha) \cdot S'(q_{text}, d_{text}) + \alpha \cdot S''(q_{time}, d_{time})$$

where the mixture parameter α indicates the importance of textual similarity $S'(q_{text}, d_{text})$ and temporal similarity $S''(q_{time}, d_{time})$. Both similarity scores must be normalized, e.g., divided by the maximum scores, in order to the final score $S(q, d)$. $S'(q_{text}, d_{text})$ can be measured using any of existing text-based weighting functions. $S''(q_{time}, d_{time})$ measure temporal similarity by assuming that a temporal expression $t_q \in q_{time}$ is generated independently from each other, and a two-step generative model was used [1]:

$$S''(q_{time}, d_{time}) = \prod_{t_q \in q_{time}} P(t_q | d_{time}) = \prod_{t_q \in q_{time}} \left(\frac{1}{|d_{time}|} \sum_{t_d \in d_{time}} P(t_q | t_d) \right)$$

Linear interpolation smoothing will be applied to give the probability $P(t_q | t_d)$ for an unseen query temporal expression t_q in d . In the next section, we will explain how to estimate $P(t_q | t_d)$ for different time-aware ranking methods.

3. TIME-AWARE RANKING METHODS

The time-aware ranking methods we study differ from each other in two main aspects: 1) whether or not time uncertainty is concerned, and 2) whether the publication time or the content time of a document is used in ranking. LMT ignores time uncertainty and it exploits the content time of d . LMT can be calculated as:

$$P(t_q | t_d)_{LMT} = \begin{cases} 0 & \text{if } t_q \neq t_d, \\ 1 & \text{if } t_q = t_d. \end{cases}$$

where $t_d \in ContentTime(d)$, and the score will be equal to 1 iff a temporal expression t_d is exactly equal to t_q . LMTU concerns time uncertainty by assuming equal likelihood for any time interval t'_q that t_q can refer to, that is, $t_q = \{t'_q | t'_q \in t_q\}$. The simplified calculation of $P(t_q | t_d)$ for LMTU is given as:

$$P(t_q|t_d)_{LMTU} = \frac{|t_q \cap t_d|}{|t_q| \cdot |t_d|}$$

where $t_d \in ContentTime(d)$. The detailed computation of $|t_q \cap t_d|$, $|t_q|$ and $|t_d|$ can be referred to [1].

TS ignores time uncertainty. $P(t_q|t_d)_{TS}$ can be computed similarly to $P(t_q|t_d)_{LMT}$, but t_d is corresponding to the publication time of d instead of the content time as computed for LMT. TSU exploits the publication time of d as done for TS, but it also takes time-uncertainty into account. $P(t_q|t_d)_{TSU}$ is defined using an exponential decay function:

$$P(t_q|t_d)_{TSU} = DecayRate^{\lambda \cdot \frac{|t_q - t_d|}{\mu}}$$

$$|t_q - t_d| = \frac{|tb_i^q - tb_i^d| + |tb_u^q - tb_u^d| + |te_i^q - te_i^d| + |te_u^q - te_u^d|}{4}$$

where $t_d = PubTime(d)$, $DecayRate$ and λ are constant, $0 < DecayRate < 1$ and $\lambda > 0$, and μ is a unit of time distance. The main idea is to give a score that decreases proportional to the time distance between t_q and t_d . The less time distance, the more temporally similar they are.

FuzzySet measures temporal similarity using a fuzzy membership function and it exploits the publication time of d for determining temporal similarity. $P(t_q|t_d)_{FuzzySet}$ is given as:

$$P(t_q|t_d)_{FuzzySet} = \begin{cases} 0 & \text{if } t_d < a_1, \\ f_1(t_d) & \text{if } t_d \geq a_1 \wedge t_d \leq a_2, \\ 1 & \text{if } t_d > a_2 \wedge t_d \leq a_3, \\ f_2(t_d) & \text{if } t_d > a_3 \wedge t_d \leq a_4, \\ 0 & \text{if } t_d > a_4. \end{cases}$$

where $t_d = PubTime(d)$. $f_1(t_d)$ is $\left(\frac{a_1 - t_d}{a_1 - a_2}\right)^n$ if $a_1 \neq a_2$, or 1 if $a_1 = a_2$. $f_2(t_d)$ is $\left(\frac{a_4 - t_d}{a_4 - a_3}\right)^m$ if $a_3 \neq a_4$, or 1 if $a_3 = a_4$. The parameters a_1, a_4, n, m are determined empirically.

4. EXPERIMENTS

The New York Times Annotated Corpus is used and 40 queries from [1] obtained using the Amazon Mechanical Turk. Note that, a standard dataset, e.g., TREC, is not applicable because queries are not time-related, and judgments are not targeted towards temporal information needs.

Documents are indexed and retrieved using the Apache Lucene version 2.9.3. There are two modes for retrieval [1]: 1) *inclusive* and 2) *exclusive*. For *inclusive*, both query terms and a temporal expression comprise a query q_{text} . For *exclusive*, only query terms constitute q_{text} , and a temporal expression is excluded from q_{text} . The baseline is the textual similarity $S'(q_{text}, d_{text})$, i.e., the Lucene's default weighting function, using *inclusive* mode denoted TFIDF-IN.

The smoothing parameter is set to 0.1. Parameters for TSU are $DecayRate = 0.5$, $\lambda = 0.5$, and $\mu = 6$ months. Parameters for FuzzySet are $n = 2$, $m = 2$, $a_1 = a_2 - (0.25 \times (a_3 - a_2))$, and $a_4 = a_3 + (0.50 \times (a_3 - a_2))$. The effectiveness is measured as the precision at 1, 5 and 10 documents (P@1, P@5 and P@10), mean average precision (MAP), and mean reciprocal rank (MRR). The sensitivity of the effectiveness to the mixture parameter α is depicted in Figure 1. The results show that the effectiveness of LMT and LMTU decreases when α is increased, whereas the effectiveness of all other methods slightly increases with the value of α .

Table 1 shows the best performing results of each method. In general, all time-aware ranking methods outperform the baseline significantly, except LMT. For each time-aware ranking, the effectiveness when retrieved using *exclusive* is better

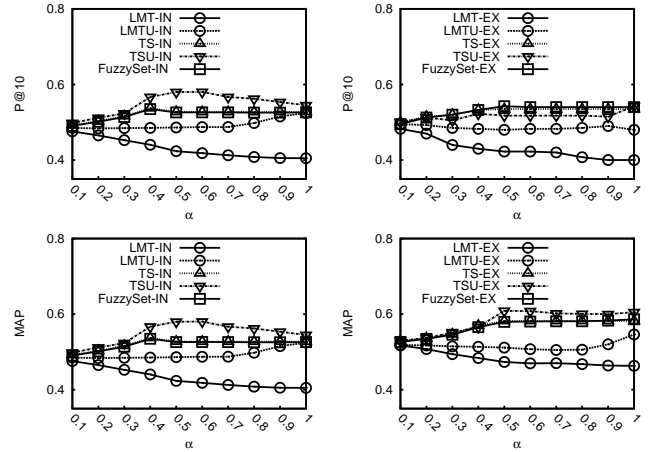


Figure 1: Sensitivity of P@10 and MAP to the mixture parameter α for both retrieval modes.

Table 1: Effectiveness of different ranking methods, in bold indicates statistically improvement over all other methods using t-test ($p < 0.05$).

Method	P@1	P@5	P@10	MAP	MRR
TFIDF-IN	.38	.43	.41	.49	.56
LMT-IN	.43	.41	.41	.48	.57
LMTU-IN	.48	.47	.45	.52	.68
TS-IN	.45	.49	.48	.54	.61
TSU-IN	.65	.51	.49	.58	.76
FuzzySet-IN	.45	.49	.48	.53	.61
LMT-EX	.38	.42	.48	.52	.55
LMTU-EX	.48	.48	.50	.55	.68
TS-EX	.48	.52	.53	.58	.63
TSU-EX	.68	.54	.54	.61	.77
FuzzySet-EX	.48	.53	.54	.59	.64

than *inclusive*. TSU performs best among all methods in both *inclusive* and *exclusive* modes, and it outperforms all other methods significantly for P@1, MAP and MRR.

5. CONCLUSIONS

Time-aware ranking methods show better performance compared to a method based on only keywords. When the time-uncertainty is taken into account, the effectiveness is improved significantly. Even though TSU gains the best performance among other methods, the usefulness of TSU is still limited for a document collection with no time metadata, i.e., the publication time of documents is not available. On the contrary, LMT and LMTU can be applied to any document collection without time metadata, but the extraction of temporal expressions is needed.

6. REFERENCES

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