Weighted inverse document frequency and vector space model for hadith search engine

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ABSTRACT

Hadith is the second source of Islamic law after Qur’an which make many types and references of hadith need to be studied. However, there are not many Muslims know about it and many even have difficulties in studying hadiths. This study aims to build a hadith search engine from reliable source by utilizing Information Retrieval techniques. The structured representation of the text that used is Bag of Word (1-term) with the Weighted Inverse Document Frequency (WIDF) method to calculate the frequency of occurrence of each term before being converted in vector form with the Vector Space Model (VSM). Based on the experiment results using 380 texts of hadith, the recall value of WIDF and VSM is 96%, while precision value is just around 35.46%. This is because the structured representation for text that used is bag of words (1-gram) that can not maintain the meaning of text well.

Keywords:
Classification
Convolutional neural network
Deep learning
Glove
Indonesian language process
Natural language processing
Text mining

1. INTRODUCTION

Hadith are all the words, deeds, decrees and approvals of the Prophet Muhammad which are made provisions or laws in Islam. Hadith is used as a source of law in Islam besides the Qur’an, Ijma’ (the agreement of the scholars in establishing a legal law in religion based on the Qur’an and Hadith in a case that occurred) and Qiyas (establish a law for a new case that does not exist yet), where in this case, the position of the hadith is the second source of law after the Qur’an [1-5]. Studying and practicing the contents of the hadith in daily life is highly important for Muslims [6]. However, many fake hadiths that appear, it is necessary to have a selective in studying hadith. Many weak and fake hadiths are circulating among Muslims because of the lack of selective nature in hearing the hadith, as a result there are irregularities in social life. It is necessary to study the hadith required by a more expert to explain the hadith and references that have been guaranteed correct.

Search engine technology as one of Information Technology implementation is a computer program that designed to search specific data based on input keywords [7-9]. Most of the search engines that already exist and are widely used today provide the results of data acquisition that has been sorted based on the level of relevance of the keywords we input. Today, search engine technology is more than database query. To increase the level of relevance of data, search engines can not be separated from the Information Retrieval (IR) and Text Mining (TM). IR is related with TM method, either text classification or text clustering to find the best result based on input keywords [8, 10, 11]. Even, Google Search Engine [12], Google Scholar [13],
weighted inverse document frequency and vector space model for hadith search… (Septya Egho Pratama)

2 RESEARCH METHOD

Research activity of this research that provided in the Figure 1 is begin from preparing data collection of Hadith, implementing IR and TM technique that preparing text data which is unstructured into structured representation in text pre-processing process, then counting WIDF and conducting VSM algorithm. Next, the performance of WIDF and VSM algorithm is tested with some scenarios and the result is evaluated using Recall, Precision, and Accuracy value.

2.1 Information Retrieval and Text Mining

Information Retrieval (IR) is a technique for finding relevant information according to the keywords entered [26-29]. While Text Mining (TM) is a technique for finding insight knowledge or important information from a collection of text documents [30-32]. Actually, IR and TM are very related, it can be said that IR is a part of TM, but IR is not yet TM. Because IR does not always implement a Data Mining (DM) technique such as classification or clustering [10]. However, the IR certainly does several TM stages, especially at the Pre-processing stage.

2.2 Weighted Inverse Document Frequency (WIDF)

In IR techniques that apply the concept of Text Mining, all the words that searched do not have the same weight. Giving a weight to a word is done by giving the frequency value of a word as a weight. The greater the appearance of words in the document will provide greater value relevance. The weighting method used in this study is Weighted Inverse Document Frequency (WIDF). The WIDF method is a development of the Term Frequency and Inverse Document Frequency (TF-IDF) method where the weakness...
of the TF-IDF method is that all documents containing certain terms are treated the same as binary calculations, while the WIDF method adds frequency features and document collections [25, 27, 33, 34]. The formula for the WIDF method is shown in (1).

\[
WIDF(d, t) = \frac{TF(d, t)}{\sum_i TF(i, t)}
\]  

(1)

Where \( d \) is a document collection, \( t \) is word or term, \( i \) is a related document. Then, \( TF (d, t) \) is the appearance of a word \( (t) \) in a document divided by \( TF (i, t) \), which is the total number of words \( (t) \) in the related document \( (i) \).

2.3. Vector Space Model (VSM)

Similarities between documents that defined based on bag-of-words representations in this research are converted to a vector space model. This model was introduced by Salton and has been used widely [35]. In VSM, each document in the database and input keywords are represented by a multi-dimensional vector or vector space dimension, where the dimensions correspond to the number of words in the document involved [23, 35, 36]. The document is represented as a vector that has distance and direction. In the VSM, a term is represented by a vector space dimension. A \( d \) document and a \( q \) query are represented as \( t \)-dimensional vectors as shown in Figure 2.

![Vector representation](image)

Figure 2. Vector representation

The VSM calculation process goes through the word weighting calculation stages, usually using the TF-IDF method. TF (Term Frequency) is the number of words appearing in a document while the IDF (Inverse Document Frequency) is the number of documents taken by the system where the term appears in it. However, in this research use WIDF. After that, calculate the length of each word weight in the query and document. Calculation of the length of the query and document weights using (2) and (3).

\[
|q| = \sqrt{\sum_{j=1}^{t} (W_{iq})^2}
\]

(2)

\[
|d_j| = \sqrt{\sum_{i=1}^{t} (W_{ij})^2}
\]

(3)

With \( |q| \) is the length of the query, and \( W_{iq} \) is the \( i \)th query weight of the document, so the length of the query \( (|q|) \) is calculated to get the length of the query from the document query weight \( (W_{iq}) \) called by the system. The length of a query can be calculated by the root equation of the number of squares of the query. With \( |d_j| \) is the length of the document, and \( W_{ij} \) is the weight of the \( i \) document, then the length of the document \( (|d_j|) \) is calculated to get the length of the document from the weight of the document \( (W_{ij}) \) called by the system. The length of a document can be calculated by the root equation of the number of squares of the document. Calculation of measurement of the similarity of query documents (inner product), using (4). Similarity between query and document or \( \text{Sim}(q, d) \) is directly proportional to the number of query weights \( (q) \) multiplied by document weight \( (d) \) and inversely proportional to the root of the number of squares \( (|q|) \) multiplied by the root of the number of squares of the document \( (|d|) \). Similarity calculations produce document weights that are close to value 1 or produce document weights that are greater than the values generated from inner product calculations.

\[
\text{Sim}(q, d_j) = \frac{q_d_j}{|q||d_j|} = \frac{\sum_{i=1}^{t} W_{iq} W_{ij}}{\sqrt{\sum_{i=1}^{t} (W_{iq})^2 \sqrt{\sum_{i=1}^{t} (W_{ij})^2}}}
\]

(4)
2.4. Recall and Precision Evaluation

Recall and Precision evaluation aims to obtain information on search results obtained by the system. Precision is the level of accuracy or relevancy between the information that requested with input keywords and the informations that given by the system, while the Recall value is the level of success of the system in finding back information [37-39].

\[
R = \frac{\text{Number of relevant items retrieved}}{\text{Total number of relevant items in collection}}
\]  

\[
P = \frac{\text{Number of relevant items retrieved}}{\text{Total number of items retrieved}}
\]

Based on (5) and (6), R being Recall, where R value is obtained by comparing the Number of relevant items retrieved with the Total number of relevant items in the collection. Recall is a document that is called from the system according to user requests that follow the pattern of the system. The greater Recall value cannot be said of a good system or not. Then, P being Precision, where P value is obtained by comparing the Number of relevant items retrieved with the Total number of items retrieved. Precision is the number of documents that are called from the relevant database after being assessed by the user with the required information. The greater the value of precision, the system can be said to be good.

3. RESULT AND ANALYSIS

In this section, the results of this study based on the research activities is presented as it shown in Figure 1, and the comprehensive analysis is also discussed.

3.1. Collecting Text Data of Hadith

The data used in this research is in the form of Indonesian translation hadith text data that obtained from the Book of Bulughul Maram [40], which contains about 1,596 hadiths (but in this research only use 380 hadiths). The book of Bulughul Maram is a thematic hadith book containing the hadiths which are used as sources of Islamic law making by fiqh experts, especially from the Imam Shafi’i and written by Ibn Hajar Al-Aqsalani based on his memorization without looking at the original book. This book includes the book of fiqh which received global recognition and is also widely translated throughout the world in the form of books and ebooks. So far, the Book of Bulughul Maram is only in the book or ebook version, there is no information system that can collect the data of the hadith, making it difficult for us to search for the hadiths that we want based on certain keywords.

3.2. Text Pre-processing

Text pre-processing is an important phase in Text Mining to prepare text data well before conducting the mining process [41, 42], among others tokenizing, casefolding, cleaning text data, stopwords removal and stemming. Tokenizing and casefolding prepare text data to be easy to change into structured representation with specific and uniform term. Stopwords removal can reduce the dimension of text data with remove all unimportant words. While stemming process is also important pre-processing phase. For Indonesian language, stemming process can maintain the meaning of text well, because the word with affixes is a verbs that contain the meaning of text [43, 44]. Even tough, in several research in text mining, the stemming process does not give a big effect in accuracy [45]. Stemming process is depend on the language, from many Indonesian stemming algorithm [46-49], this research use an improved Porter algorithm that modified based on Indonesian language [50]. The example result of text pre-processing is available in Table 2 which is pre-processing result from the text hadits example from Table 1 that provided in Indonesian Language.

3.3. Analysis of Weighted Inverse Document Frequency

After text pre-processing, as bag-of-words representation, every word is a term. Using (1), frequency of each term is calculated. The example result of WIDF for hadith text is available in the Table 3 which is counted from the terms in from the result of text pre-processing in Table 2. In addition to documents, word weight calculations are also performed on keywords, of course before the text mining process is performed first. Because in keywords, the word used is already in a simple form, then just calculate the weight of the word. For example, the keyword is “sedekah”, with the same process the WIDF value of “sedekah” is 0.125.
Table 1. The Example of Hadith Data Text

| Number | Hadith Text                                                                 |
|--------|-----------------------------------------------------------------------------|
| 1      | Dari Abu Hurairah Radyiallaha 'ahu bahwa Rasulullah Shalallahu 'alaihi wa Sallam pernah ditemukan: Wahai Rasulullah Shalallahu 'alaihi wa Sallam, sedekah apakah yang paling mulia? Beliau menjawab: “Sedekah orang yang tak punya, dan mulialah memberi sedekah atas orang yang banyak tanggungannya. Dikeluarkan oleh Ahmad dan Abu Dawud.”                                                |
| 2      | Dari Abu Said Al-Khudy Radyiallaha 'ahu bahwa Zainab, istri Abu Mas'ud, bertanya: Wahai Rasulullah, baginda telah memerintahkan untuk bersedekah hari ini, dan aku mempunyai perhiasan yang hendak saya sedekahkan, namun Ibnu Mas'ud menganggap bahwa dirinya dan anaknya lebih berhak untuk aku beri sedekah. Lalu Nabi Shalallahu 'alaihi wa Sallam bersabda: “Ibnu Mas'ud memang benar, suamimu dan anakmu adalah orang yang lebih berhak untuk engkau beri sedekah.” Ribwayat Bukhari. |
| 3      | Dari Samurah Ibnu Jundab Radyiallaha 'ahu bahwa Rasulullah Shalallahu 'alaihi wa Sallam bersabda: “Meminta ma'rip adalah cakaran seseorang terhadap mukannya sendiri, kecuali meminta kepada penguasa atau karena suatu hal yang amat perlu.” Hadits shahih riwayat Tirmidzı. |
| 4      | Dari Abu Hurairah Radyiallaha 'ahu bahwa Rasulullah Shalallahu 'alaihi wa Sallam bersabda: “Umrah ke umrah menghapus dosa antara keduanya, dan tidak ada pahala bagi haji mabrur kecuali urge.” Muttafaq Alaihi. |
| 5      | Dari Uqbah Ibnu Amir bahwa dia mendengar Rasulullah Shalallahu 'alaihi wa Sallam bersabda: “Setiap orang berhak untuk membagikan sedekahnya sehingga ia diputuskan amal perbuatanannya antara manusia.” Ribwayat Ibnu Hibban dan Hakim. |

Table 2. The Example of Text Pre-Processing Result from the Hadith Text in Table 1

| Document 1 (d1) | Document 2 (d2) | Document 3 (d3) | Document 4 (d4) | Document 5 (d5) |
|----------------|----------------|----------------|----------------|---------------|
| abu hurairah   | abu said       | samurah        | abu said       | ubah          |
| radyiallaahuanhu | alkhudy        | jundab         | radyiallaahuanhu | amr           |
| rasulullah     | radyiallaahuanhu | radayiallaahuanhu | rasulullah     | dengar        |
| shalallahaualihi | zainab         | shalallahaualihi | shalallahaualihi | shalallahaualihi |
| salam          | istri          | ...            | ...            | ...           |
| ...            | ...            | ...            | ...            | ...           |
| jawaab         | sedekah        | ...            | ...            | ...           |
| sedekah        | hari           | kewal  pahala   | ...            | ...           |
| orang          | punya          | ...            | ...            | ...           |
| punya          | perhiasan      | ...            | ...            | ...           |
| mulai          | sedekah        | hal            | mabrur        | ibnu          |

Table 3. The Example of WIDF Calculation for Hadith Text

| Word (t) | \(TF(d_i)\) | \(TF(t_j)\) | \(TF(d_i) / TF(t_j)\) |
|----------|-------------|-------------|------------------------|
| abu      | 1           | 1           | 1                      |
| hurairah | 1           | 1           | 1                      |
| radyiallaahuanhu | 2   | 1           | 2                      |
| rasulullah | 2   | 1           | 2                      |
| shalallahaualihi | 2   | 1           | 2                      |
| salam    | 2           | 1           | 2                      |
| tanya    | 1           | 1           | 1                      |
| sedekah  | 3           | 4           | 0,75                   |
| mulia    | 1           | 0           | 0                      |
| jawaab   | 1           | 0           | 0                      |
| orang    | 2           | 1           | 2                      |
| punya    | 1           | 1           | 2                      |
| mulai    | 1           | 0           | 0                      |
| beri     | 1           | 0           | 0                      |
| hadits   | 1           | 0           | 0                      |
| shahih   | 1           | 0           | 0                      |
| ibnu     | 1           | 2           | 2                      |
| hibban   | 1           | 0           | 0                      |
| hakim    | 1           | 0           | 0                      |

3.4. Analysis of Vector Space Model

After weighting the words, the next step is to calculate the match between the keywords and documents using the VSM algorithm. The first step in this algorithm is to calculate the multiplication of the weight scale by multiplying the keyword weights with the document and then adding them up. The next step is to calculate the length of the vector by squaring all the word weights and adding them together. The final step is to find a match/similarity value between the keyword and the document by dividing the value of the
Scalar weight multiplication by the length of the vector. Examples of results from scalar multiplication and vector length calculations are in Table 4 (the final result value has been rounded). The results are obtained from calculations using (2), (3), and (4). For counting similarity value between input keyword and document is calculated using Cosine Similarity with (4). The similarity value is provided in Table 5 with the highest order value is Document 2, followed by Document 1 and Document 5. So, system will be produced Document 1, 2, and 5 that related with keyword “sedekah”.

| Word (t) | Scalar Multiplication | Vector Length Calculation |
|----------|-----------------------|----------------------------|
|          | (d,q)                 | Wq                         |
|          | d1 | d2 | d3 | d4 | d5 | q | d1 | d2 | d3 | d4 | d5 | q |
| abu      | 0.4 | 0.4 | 0   | 0.2 | 0   | 0   | 0   | 0   | 0   | 0   | 0.16 | 0.16 | 0 | 0.04 | 0 | 0 |
| hazairah| 0.5 | 0   | 0   | 0.5 | 0   | 0   | 0   | 0   | 0   | 0   | 0.25 | 0   | 0 | 0.25 | 0 | 0 |
| radyiallaah uanhu| 0.3 | 0.3 | 0.3 | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0.06 | 0.06 | 0 | 0.06 | 0 | 0 |
| rasulallah| 0.3 | 0.2 | 0.2 | 0   | 0.2 | 0   | 0   | 0   | 0   | 0   | 0.11 | 0.03 | 0.03 | 0.03 | 0.03 |
| shallaalah ualaihi| 0.3 | 0.2 | 0.2 | 0   | 0.2 | 0   | 0   | 0   | 0   | 0   | 0.11 | 0.03 | 0.03 | 0.03 | 0.03 |
| sallam    | 0.4 | 0   | 0   | 0.2 | 0   | 0   | 0   | 0   | 0   | 0   | 0.16 | 0   | 0.04 | 0.04 | 0.04 |
| tanya     | 0.5 | 0.5 | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0.25 | 0.25 | 0 | 0.00 | 0 | 0 |
| sedekah  | 0.4 | 0.5 | 0   | 0   | 0.1 | 0.1 | 0.1 | 0   | 0   | 0   | 0.14 | 0.25 | 0 | 0.01 | 0 | 0 |
| mutia    | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0.1   | 0   | 0 | 0.00 | 0 | 0 |
| jawah    | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0.1   | 0   | 0 | 0.00 | 0 | 0 |
| orang    | 0.4 | 0.2 | 0.2 | 0   | 0.2 | 0   | 0   | 0   | 0   | 0   | 0.16 | 0.04 | 0.04 | 0.04 | 0.04 |
| punya    | 0.5 | 0.5 | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0.25 | 0.25 | 0 | 0.00 | 0 | 0 |
| mulai    | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0.11 | 0.45 | 0 | 0.00 | 0 | 0 |
| beri     | 0.3 | 0.7 | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0.11 | 0.45 | 0 | 0.00 | 0 | 0 |
| hadits   | 0.5 | 0   | 0.5 | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0.25 | 0.25 | 0 | 0.00 | 0 | 0 |
| shahih   | 0.5 | 0   | 0.5 | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0.25 | 0.25 | 0 | 0.00 | 0 | 0 |
| ibnu     | 0.2 | 0.3 | 0.2 | 0   | 0.3 | 0   | 0   | 0   | 0   | 0   | 0.03 | 0.11 | 0.03 | 0.11 | 0.11 |
| hibban   | 0.5 | 0   | 0   | 0   | 0.5 | 0   | 0   | 0   | 0   | 0   | 0.25 | 0   | 0.00 | 0.25 | 0.25 |
| hakim    | 0.5 | 0   | 0   | 0   | 0.5 | 0   | 0   | 0   | 0   | 0   | 0.25 | 0   | 0.00 | 0.25 | 0.25 |

\[
\sum W_{d,q} = 0.1, 0.1, 0.0, 0.0, 0.0
\]

\[
\sum \frac{1}{W_q} = 10.7, 15.0, 8.39, 9.76, 9.93, 0.0
\]

\[
\sum \frac{2}{W} = 94, 47, 96, 1, 6, 16
\]

\[
\sum \frac{2}{W} = 3.28, 3.87, 2.89, 3.12, 3.15, 0.1
\]

3.5. Result of Hadith Search Engine Testing

The experiment is conducted using 380 of Hadith text data from the Book of Bulughul Maram. Figure 3 shows the implementation of Hadith search engine with web-based system. There are 5 keywords with different number of term for testing scenario that conducted to evaluate the output of system, among others “sedekah”, “zakat fitrah”, “zakat harta rikaz”, “sedekah hutang anak yatim”, and “zakat hewan ternak dan tanaman”. The result of those experiments use Recall and Precision value that provides in the Table 6 and Figure 4. The analysis and evaluation of experiment result is explained in Section 4.6.
Figure 3. The example of Hadith search engine implementation

Table 6. The Experiment Result of Hadith Search Engine Implementation

|                  | Total of       | 1st Testing | 2nd Testing | 3rd Testing | 4th Testing | 5th Testing |
|------------------|----------------|-------------|-------------|-------------|-------------|-------------|
|                  | Total Hadith   | "Sedekah"  | "Zakat Fitr"| "Zakat Harta" | "Sedekah Hutang Anak Yatim" | "Zakat Hewan ternak dan Tanaman" |
| Data called      | 12             | 35          | 58          | 44          | 51          |
| Relevant data that is called | 12         | 5           | 3           | 11          | 15          |
| Irrelevant data called | 12       | 30          | 55          | 33          | 36          |
| Relevant data that is not called | 3       | 0           | 0           | 0           | 0           |
| The sum of all relevant data | 15       | 5           | 3           | 11          | 15          |
| Recall           | 80%            | 100%        | 100%        | 100%        | 100%        |
| Precision        | 100%           | 14.28%      | 8.62%       | 25%         | 29.41%      |

Figure 4. Graphics of experiment result

3.6. Analysis and Evaluation of Experiment and Testing Result

Based on the experiment result, this research found that:

1. Hadith search engine using WIDF and VSM success in finding the information (in this case is hadiths) in accordance with the input keywords well. It is proven by the average of Recall value which is quite high.
around 96% from 5 types of experiment. While, the relevancy of hadiths that produced is low, because the average of Precision value is small, just around 35.46%.

2. The small Precision value that show that result of hadiths from search engine most of then are not relevant or not related with the purpose of the hadith that the user is looking for. This can be caused by the following things:
   a. The search engine is used bag-of-word as structured text representation. Bag-of-word representation is a structured representation from text, where text data is represented by collection of word, one word one term [51, 52]. So that, if the keyword that more than one word, it will be separated per word and not in n-gram form. This analysis is supported by the result of precision that the low precision value occurs in the input keywords with n-term/n-gram. For example, if the input keyword is “zakat fitrah”, the system will produce the hadiths that contain “zakat” and “fitrah”, whereas “zakat fitrah” is a single entity, so when there is a hadith that contains the word “fitrah” even though it is not related to zakat it will still be produced.
   b. Indonesian language is unique, still a lots of problem in Indonesian language besides punctuation, abbreviation, and character in the bracket, one of them in word with affixes [53]. The low precision value can be affected by the result of stemming process. There are letters that melt when given certain affixes, including "k", "p", "t", and "s" [54, 55]. So, if there is a word “purify yourself” when done stemming it will become “pure self”, so the search engine should produce traditions related to purification. Back to the analysis in point 1, search engines will produce traditions that contain “holy” and “self”, which are not all in accordance with the intent of the keywords entered, including traditions that only contain the word “self.” However, if the process stemming is removed, the traditions will produce traditions containing “purify” and “self”. There will be traditions related to purification that are produced and relevant, but search engines will not produce traditions related to purification that do not contain the word “purify”. For example the traditions about purification but contain words other than “purify”, such as containing the words “sanctified”, “purified”, even "holy" itself will not be displayed, so that more traditions are wasted if the stemming process is not done.

3. Poor results in terms of the precision or relevance of the information that produced does not mean that the WIDF and VSM algorithms are wrong. However, it is because the text representation that used (bag-of word or 1-gram) is not good in maintaining the meaning of text documents. Nowadays, there are many Text Mining researches that prove and use multiple of words or n-grams that can maintain the meaning of text better [56-61]. Even Google search engines that implement IR and TM technology do not use 1-gram, because when we search for the word “Information Retrieval” (without quoting as input keywords) on Google search engines, the information that will be generated is related to “Information”, “Retrieval” and “Information Retrieval”.

4 CONCLUSION
This study use Weighted Inverse Document Frequency and Vector Space Model as algorithms to build search engine of Hadith which is an important source for Muslim. Based on the experiments that were conducted, this study has high Recall that means success to produce information of Hadiths in accordance with input keywords. However, the precision value is small that means most of the information that is produced are not relevant with the intent of the keywords entered. It is caused by several factors, which not due to the algorithm used, but due to the text representation used. Therefore, for the further research, besides hadith data that needs to be completed so that it is rich in information, the text representation used is also better which includes multiple of words to maintain the meaning of better and the resulting hadith information is more relevant. In addition, further research is also needed related to the effect of WIDF on search results. Besides that algorithms can also be applied in addition to VSM for the search engine hadith.

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