Web Search Engine Based Naming Procedure for Independent Topic
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Abstract—In recent years, the number of document data has been increasing since the spread of the Internet. Many methods have been studied for extracting topics from large document data. We proposed Independent Topic Analysis (ITA) to extract topics independent of each other from large document data such as newspaper data. ITA is a method for extracting the independent topics from the document data by using the Independent Component Analysis. The topic represented by ITA is represented by a set of words. However, the set of words is quite different from the topics the user imagines. For example, the top five words with high independence of a topic are as follows. Topic1 = {"scor", "game", "lead", "quarter", "rebound"}. This Topic1 is considered to represent the topic of "SPORTS". This topic name "SPORTS" has to be attached by the user. ITA cannot name topics. Therefore, in this research, we propose a method to obtain topics easy for people to understand by using the web search engine, topics given by the set of words given by independent topic analysis. In particular, we search a set of topical words, and the title of the homepage of the search result is taken as the topic name. And we also use the proposed method for some data and verify its effectiveness.

Keywords—Independent topic analysis, topic extraction, topic naming, web search engine.

I. INTRODUCTION

There are a lot of studies of topic extraction from a large amount of document data. In this paper, we focus on topic extraction which is one of the challenges of text mining. The topic is the information represented by a co-occurrence of words between the large number of documents. As a method of topic extraction, there are a lot of studies of topic model such as PLSA (Probabilistic Latent Semantic Analysis) [4] proposed by Hofmann et al. and LDA (Latent Dirichlet Allocation) [1] proposed by Blei et al.. The topic model is a method of extracting the topic focusing on probabilistic generative model[2]. The topic model generates the model between the document, word and topic. The topic is latent variable in the topic model. Moreover, the topic model represents the bias of the topic with the document by defining the distribution of the topic for each document. In many of the topic model, a document is represented as the bag of its words (bag-of-words), disregarding grammar and even word order but keeping multiplicity. In the bag-of-words, it commonly used the frequency of the words or tf-idf[8]. It is possible to represent the probability model of the relationship between the document, the word and the topic by using the topic model. However, the PLSA and the LDA is not focus on the relation between topics as correlation relationship or independence.

On the other hand, LSI (Latent Semantic Indexing)[3] and ITA (Independent Topic Analysis)[9] are focus on the relation between topics. LSI is able to extract the topic as large variance of the word or the document. It is possible to extract the topic without the correlation relationship between each topic by using LSI. The topic without the correlation relationship between each topic shows that there is no linear relationship such as a topic increase as well as another topic increase. ITA is able to extract the highly independent topic by using ICA (Independent Component Analysis)[6]. ICA is a computational method for separating a multivariate signal into additive subcomponents in signal processing. The highly independent topic show the mutual information between each topic is small topic. It is easy to make document summarization with a large of information by extracting highly independent topic. The independent topic contains the topic without the correlation relationship. In other words, the independent topic is not equal to the topic without the correlation relationship. Note that when the topic in the document is normal distribution, the independent topic is equal to the topic without the correlation relationship. However, the topic in actual document data is not necessarily the normal distribution. Thus, it is necessary to extract the independent topic for extracting the topic which is small mutual information.

In this paper, we describe the ITA which is topic extraction method focusing on the independence of the topics. However, the extracted independent topic are expressed the collection of important words. So it is difficult to understand the independent topics. In this study, we propose a method that help to naming independent topic. We propose method that help to naming independent topic with Web Search Engine.

In the following sections, we introduce the ITA (Independent Topic Analysis) in Section II. In section III, describe the proposed method’s concept and algorithm. In Section IV and Section V, we show the experimental setup and experimental result. Finally in Section VI, we describe the conclusion and future works.

II. ITA: INDEPENDENT TOPIC ANALYSIS

In this section, we introduce the Independent Topic Analysis (ITA) [10]. This method extract to topics from the document data by Independent Component Analysis (ICA)[6]. In the followings that a small letter expresses scalar, a bold small letter expresses vector, and a bold capital letter expresses matrices. As common variables, \( t \in \{1, \ldots, k\} \) express topic variables, \( d \in \{1, \ldots, n\} \) express document variables, and \( w \in \{1, \ldots, m\} \) express word variables.
Firstly, we describe the concepts of ITA. Matrices \( \mathbf{V} \) have \( m \) rows and \( k \) columns, which called “importance of the word \( w \) in the topic \( t \)”. And vector \( \mathbf{v}_t \) represent the \( t \)-th columns of vector of matrices \( \mathbf{V} \). The vector \( \mathbf{v}_t \) is \((v_{1,t}, \ldots, v_{m,t})^T\). Vector \( \mathbf{v}_t^T \) represent the transposition of the \( w \)-th rows of vector of matrices \( \mathbf{V} \). The vector \( \mathbf{v}_w \) is \((v_{w,1}, \ldots, v_{w,k}) \). Matrices \( \mathbf{U} \) have \( n \) rows and \( k \) columns, which called “importance of the document \( d \) in the topic \( t \)”. And vector \( \mathbf{u}_t \) represent the \( t \)-th columns of vector of matrices \( \mathbf{U} \). The vector \( \mathbf{u}_t \) is \((u_{1,t}, \ldots, u_{n,t})^T\). Vector \( \mathbf{u}_d^T \) represent the transposition of the \( d \)-th rows of vector of matrices \( \mathbf{U} \). The vector \( \mathbf{u}_d \) is \((u_{d,1}, \ldots, u_{d,k}) \). In the same way, matrices \( \mathbf{A} \) have \( n \) rows and \( m \) columns, which called “frequency of word \( w \) in a document \( d \)”. And \( \mathbf{a}_w \) represent the \( w \)-th columns of vector of matrices \( \mathbf{A} \). The vector \( \mathbf{a}_w \) is \((a_{1,w}, \ldots, a_{n,w})^T\). Vector \( \mathbf{a}_d^T \) represent the transposition of the \( d \)-th rows of vector of matrices \( \mathbf{A} \). The vector \( \mathbf{a}_d \) is \((a_{d,1}, \ldots, a_{d,m}) \).

We use the kurtosis of fourth moment of the standard score as the measure of topic of independence. We define the measure of topic of independence as follows.

\[
\sum_{w} \left( v_{w,t}^4 P(w) \right) - 3 \left( \sum_{w} v_{w,t}^2 P(w) \right)^2
\]

Where \( v_{w,t} \) is component of \( w \)-th rows and \( t \)-th columns of the matrix \( \mathbf{V} \). And \( P(w) \) is defined as follows.

\[
P(w) = \frac{\sum_{w} d_{d,w} a_{d,w}}{\sum_{w,m} a_{d,w}}
\]

Where \( d_{d,w} \) is component of \( d \)-th rows and \( w \)-th columns of the matrix \( \mathbf{A} \). When this measure is large, many components of matrix \( \mathbf{V} \) and \( \mathbf{U} \) become 0 value. So it is possible to express the topic only in a small number of words and documents.

Secondly, we describe the algorithm of ITA. ITA is formulated as an optimization problem as follows.

\[
\text{maximize } \sum_{t} \sum_{w} \left( \mathbf{V} \mathbf{R} \right)_{w,t}^4 P(w) - 3 \left( \sum_{w} \left( \mathbf{V} \mathbf{R} \right)_{w,t}^2 P(w) \right)^2
\]

subject to \( \mathbf{R}^T \mathbf{R} = 1 \), \( \| \mathbf{R} \| = 1 \)

Where \( \left( \mathbf{V} \mathbf{R} \right)_{w,t} \) is fourth power of each component of the matrix \( \mathbf{VR} \). In follow, we show algorithm of ITA. In this method, the number of topics \( k \) is random variable.

1) Get the matrix \( \mathbf{A} \). And using by [5], we normalize the \( \mathbf{A} \) to make \( \hat{\mathbf{A}} \).

2) Performs a singular value decomposition of the matrix \( \hat{\mathbf{A}} \), such that \( \hat{\mathbf{U}}^T \hat{\mathbf{A}} \hat{\mathbf{V}} = \hat{\mathbf{S}} \). Where \( \hat{\mathbf{S}} \) is a diagonal matrix of singular values.

3) Extract the matrix \( \mathbf{U} \), \( \mathbf{S} \) and \( \mathbf{V} \) from the matrix \( \hat{\mathbf{U}} \), \( \hat{\mathbf{S}} \) and \( \hat{\mathbf{V}} \). Extracted by \( k \) components in descending order of the value of the matrix \( \hat{\mathbf{S}} \).

4) The matrix \( \mathbf{X} \) of the topic in the \( k \)-dimensional space is defined as follows.

\[
\mathbf{X} = \mathbf{S}^{-1/2} \mathbf{U}^T \hat{\mathbf{A}}
\]

5) Independence maximization between each topic: calculate the rotation matrix \( \mathbf{R} \) of the maximum independence based on FPICA as follows.

Thus, it is possible to extract highly independent topics, such as shown in Fig. 1. We apply ITA to Los Angeles Times (LA Times) data as benchmark data. In the Table I, it is shows that the important words of extracted 6 topics by applying ITA to LA Times. The important words which are the word with the large value of \( v_{w,t} \).

However, it is difficult to understand the independent topics. Because we can only look the collection of important words of each independent topic. So, we want to name of each independent topics. Therefore, we propose a method of naming the independent topic with Web search engine. In Section III, we describe the proposed method.
TABLE I
The Important Words of the Extracted 6 Topics by Applying ITA to LA TIMES

<table>
<thead>
<tr>
<th>No.</th>
<th>important words of each topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>scor game lead quarter rebound</td>
</tr>
<tr>
<td>2</td>
<td>bush polic budget reagan presid</td>
</tr>
<tr>
<td>3</td>
<td>million earn bank quarter billion</td>
</tr>
<tr>
<td>4</td>
<td>soviet israel afghanistan foreign afghan</td>
</tr>
<tr>
<td>5</td>
<td>alem macmun art entertain report</td>
</tr>
<tr>
<td>6</td>
<td>polic counti olttc orange game</td>
</tr>
</tbody>
</table>

Next step, it extract the Title from the Web page of the search result. We explain the result of proposed method apply to LA Times. We show the extracted Title from HTML of the search result first. We apply proposed method to three benchmark dataset as follows.

• Los Angeles Times (LA Times)[13], [14]; the number of document \( \times \) words is 6279 \times 31472, the number of topic is 6
• Neural Information Processing Systems (NIPS)[7]; the number of document \( \times \) words is 1500\times12419, the number of topic is 4
• DAILY KOS blog (KOS blog)[7]; the number of document \( \times \) words is 3430 \times 6906, the number of topic is 9

In the experiments, the number of words to be extracted and searched is \( p = 10 \).

III. NAMING TOPICS WITH WEB SEARCH ENGINE

In this section, we describe proposed method that help to naming topics with Web search engine.

We explain the concepts of proposed method. First step, it extract the important words of independent topics. Second step, it perform an AND search using the extracted words. Next step, it extract the Title from the Web page of the search result.

We describe the algorithm of proposed method as follows.
1) Get the \( k \) independent topics by ITA.
2) Extract the \( p \) important words of each independent topic with high \( v_{w,t} \), \( t \in \ldots, k \).
4) Extract the Title from HTML of the search result first Web page by Step 3.
5) Let the title be the name of that topic.
6) Perform Step 2, 3, 4 with all independent topics.

IV. EXPERIMENTAL SET UP

In this section, we apply proposed method to three benchmark dataset as follows.

• Los Angeles Times (LA Times)[13], [14]; the number of document \( \times \) words is 6279 \times 31472, the number of topic is 6
• Neural Information Processing Systems (NIPS)[7]; the number of document \( \times \) words is 1500\times12419, the number of topic is 4
• DAILY KOS blog (KOS blog)[7]; the number of document \( \times \) words is 3430 \times 6906, the number of topic is 9

In the experiments, the number of words to be extracted and searched is \( p = 10 \).

V. EXPERIMENTAL RESULTS & DISCUSSION

In this section, we show the experimental results of applying proposed method to the benchmark data, and we discuss it. In the experiment, we perform an AND search with 10 important words of independent topics. We show some of the words used in the AND search in the Table. I and III. And we use googlesearch[15] in Python for AND search.

Firstly, we explain the result of proposed method apply to LA Times. We show that the extracted Title from HTML of the search result applying proposed method to LA Times.

<table>
<thead>
<tr>
<th>No.</th>
<th>important words of each topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>bush president bushs administration Edwards</td>
</tr>
<tr>
<td>2</td>
<td>november account electoral governor house</td>
</tr>
<tr>
<td>3</td>
<td>dean clark clarks edwardx general kerry</td>
</tr>
<tr>
<td>4</td>
<td>iraq war iraqi military troops</td>
</tr>
<tr>
<td>5</td>
<td>perseu polic voters polls vote</td>
</tr>
<tr>
<td>6</td>
<td>campaign million money edwards media</td>
</tr>
<tr>
<td>7</td>
<td>party democratic democrats votes republican</td>
</tr>
<tr>
<td>8</td>
<td>race senate democrats senate republican</td>
</tr>
<tr>
<td>9</td>
<td>sear house gop district democrat</td>
</tr>
</tbody>
</table>

Finally, we explain the result of proposed method apply to NIPS dataset. We show that the extracted Title from HTML of the search result applying proposed method to NIPS.

<table>
<thead>
<tr>
<th>No.</th>
<th>important words of each topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>network unit neural input training</td>
</tr>
<tr>
<td>2</td>
<td>model function data system weight</td>
</tr>
<tr>
<td>3</td>
<td>learning algorithm action data control</td>
</tr>
<tr>
<td>4</td>
<td>neuron cell input function training</td>
</tr>
<tr>
<td>5</td>
<td>output hidden weight layer algorithm</td>
</tr>
<tr>
<td>6</td>
<td>control object parameter recognition algorithm</td>
</tr>
<tr>
<td>7</td>
<td>task reinforcement policy function system</td>
</tr>
<tr>
<td>8</td>
<td>data visual circuit synaptic response</td>
</tr>
</tbody>
</table>

Looking at the titles, we find that Topic1 is a topic of NBA. Similarly, we find that Topic2 is a economic policies of the former U.S. president Donald Reagan, Topic3 is the earn and finance, Topic4 is a foregin topic for the U.S., Topic5 is GitHub, Topic6 is incident near Los Angeles. Topic5 is very difficult to understand. So, we access this web page, we are able to learn that the details of this LA Times dataset. From this results, the extracte title is easier to understand than a collection of words.

Secondly, we explain the result of proposed method apply
to NIPS. We show that the extracted Title from HTML of the search result applying proposed method to NIPS.

Topic1 Mind: How to Build a Neural Network (Part One)
Topic2 Build your own object classification model in SageMaker and import it to DeepLens | AWS Machine Learning Blog
Topic3 Reinforcement learning - Wikipedia
Topic4 Synapses and Memory Storage

Looking at the titles, we find that Topic1 is a topic of neural network. Similarly, we find that Topic2 is classification model, Topic3 is reinforcement learning, Topic4 is Brain Synapse. The result of NIPS, as well as the results of LA Times, the extract title is easier to understand than a collection of words.

Thirdly, we explain the result of proposed method apply to KOS Blog. We show that the extracted Title from HTML of the search result applying proposed method to KOS Blog.

Topic2 Ben Shapiro: 10 Reasons To Vote Republican In November | Video | RealClearPolitics
Topic3 CNN.com - Edwards campaign book details attacks - Jan. 21, 2004
Topic4 Poll: Bush And Kerry Tied - CBS News

Looking at the titles, we find that Topic1 is a topic of George W. Bush. Similarly, we extracted the title from Web page.

The result of KOS Blog, as well as the results of LA Times, the extract title is easier to understand than a collection of words.

In these experiments, we tried searching for the number of words easy to understand. However, we don’t know the appropriate number of words easy to understand.

And when HTML style are different, we don’t understand of title tag.

For our future works, we would like to improve these problem. And it is necessary to apply other benchmark datasets.

VI. Conclusion

In this paper, we proposed method that help to name the independent topic using the Search Engine. This methods was to solve one of the problems of the Independent Topic Analysis (ITA). The problem is that it is difficult to understand the independent topic from collection of words. To evaluate the proposed method, we implemented and tested in Python. We applied proposed method to several benchmark datasets. This experimental results show the extracted topics are easier to understand than a collection of words. However, we don’t know the appropriate number of words easy to understand.