Biogeography-Based Optimization Algorithm for Automatic Extractive Text Summarization

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KEYWORDS
Text Summarization, BBO Algorithm, Extractive Method, Online Sources, NP complete.

ABSTRACT
Given the increasing number of documents, sites, online sources, and the users’ desire to quickly access information, automatic textual summarization has caught the attention of many researchers in this field. Researchers have presented different methods for text summarization as well as a useful summary of those texts including relevant document sentences. This study selects extractive method out of different summarizing methods (e.g. abstract method). Extractive method involves summarizing text through objective extraction of some parts of a text like word, sentence, and paragraph. A summarization issue would be unsolvable by exact methods in a reasonable time with considering documents with high amount of information (NP complete). These kinds of issues are usually solved using metaheuristic methods. A biogeography-based optimization algorithm (BBO), which is a new metaheuristic method in the domain of extractive text summarization is used in this article. This method is tested on a set of Doc’s standard documents in 2002 and is analyzed, using ROUGE software. The obtained results of these tests show that this kind of method can be used as an effective method for text summarization.

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multiple documents or it can be done based on the aim of summarization such as inquiry or general summarization. Extractive summarization, some parts of a text such as a sentence or paragraph are extracted objectively. Abstract summarization which is done using linguistic methods is based on a text comprehension and a text rewritten in a few sentences. Different methods were proposed for extractive text summarization. Ledeneva et al. [4], Garcia and Ledeneva[5] presented One of the important methods in the domain of text summarization is TFIDF. In this method summarization is based on the repeated words of sentences and a reverse of repeated sentences. Repeated sentences refer to sentences of a document with the same words. In this method some parts of every sentence may be repeated in other sentences. An advantage of this method is its easy usage and its disadvantage is that some important words are repeated frequently which make summarization awful. Zhang and Li [6] presented Documents are usually written based on different subjects. That is, sentences are written in an explicit or implicit form. Some people summarize texts, using a clustering method. Based on this method, the amount of similarity among the sentences is studied according to some parameters and similar sentences are put in one cluster. Therefore, every cluster shows one subject. Then in each cluster, the sentences with the highest similarity to the subject which have obtained high scores are selected for summarization. An advantage of this method is that it is possible to identify all subjects of each text very well and a disadvantage of this method is that the number of clusters have an important role in the results of the study. There can be a large or small number of clusters. On the other hand, it is difficult to select an appropriate number of sentence clusters from one textual document Chuang and Yang [7]. In another method of extractive text summarization presented a set of data labeled by human beings are used. On the other hand, in this method, input texts and their summaries are at hand. In this method, first a text is divided into different parts based on some parameters and each part is displayed based on some features such as the amount of word repetition, word part of speech, and the number of title words. Following the extraction of the features from each part, a learning method is used to train the people who summarize the texts. Song et al.[8], and Suanmali et al. [9] presented. These methods include a decision tree, Byzih law, neural networks, and fuzzy logic. A decreased precision in the case of larger documents as well as a decrease in speed due to a large number of comparisons are the main disadvantages of this method. One of the main disadvantages of a fuzzy logic method is that the unsuitability of defined rules results in a decrease in precision. Meta-heuristic methods such as genetic algorithm (GA), [10, 11] and particle swarm optimization (PSO)[12] and bacterial foraging optimization algorithm (BFOA)[13] are another set of methods used for extractive text summarization. In meta-heuristic methods, sentences with high scores are selected. A main challenge in extractive summarization is that there is a large amount of information in documents and many studies should be done on them. So, this method cannot solve the issue. In larger texts which consist of more words, scoring and more importantly selecting sentences are very difficult. Therefore, in this method, summarization speed and precision will be decreased. In such a condition, using meta-heuristic optimization methods are helpful. Although optimization methods are not used in local minimums and maximums. A biogeography-based optimization method is used in this article. The results show that this method has better performance than other previous methods. This article is organized into five parts. In the first part of this article, an introduction is presented followed by the definition of the major concepts in the second part. In the third part of this article, the method of the study and its features are described. In the fourth part of this article, the tests are conducted and their results are compared. Finally, the fifth part concludes this study.

2. Definitions and Concepts
2-1. The process of extractive text summarization
In text summarization, important information of one source and different sources are put together for the purpose of users’ usage. In an extractive summarization method, important sentences and paragraphs of a text are put together to make a shorter form of the text [14]. This method has a lot of advantages. Some of its advantages include its simplicity, high rate of summarization, and expense reduction. Also, in this method, users spend less time for studying text information. A disadvantage of this method is that the amount of extracted sentences may be more than a normal amount. Moreover, as the
important and relevant information may be
distributed among sentences, an extractive
method cannot identify them. Extractive
summarization is done in two steps including
preprocessing and processing steps based on Fig.
1. In the preprocessing step, the end of the
sentences will be identified, the words which do
not have significant meaning are omitted, and the
root of the words is specified. In the processing
step, the amount of sentence effects and its
relationships to a main subject are identified and
a specified score is given to them. Finally,
sentences with the highest scores are selected for
text summarization.

2-2. Biogeography-based optimization method
As new global optimization algorithm a
biogeography-based optimization method (BBO)
is based on a biogeography theory and studies the
geographical distribution of biological organisms.
A biogeography-based optimization algorithm
like genetic algorithms (GA) and particle swarm
optimization (PSO) are inspired by nature. Simon
[15] presented in this algorithm, immigration of
species which are some parts of biogeography
science are used for solving the optimization
issues. In biogeography-based optimization,
every habitat is identified as an individual
member and has its own habitat suitability index
(HIS). A biogeography-based optimization
algorithm is like a genetic algorithm, with its
higher habitat suitability index in one habitat
showing a good habitat. On the other hand,
habitats with a low habitat suitability index make
themselves look like habitats with high habitat
suitability index through taking their properties.
There are two migration factors in a migration
model, namely, emigration and immigration.
These two kinds of migrations have their own
rate (λ) and output rate (μ). In a biogeography-
based optimization method, two migration factors
in a migration operator and a mutation operator
are used for predicting the habitat, which
maximizes the habitat suitability index. A good
habitat has a higher emigration rate and a lower
immigration rate as Fig. 2 [15].

\begin{equation}
  y_k(a) = \delta y_k(a) + (1 - \delta) y_j(a)
\end{equation}

\begin{equation}
  \text{Prob(immigration to } y_k) = \lambda_k
\end{equation}

\begin{equation}
  \text{Prob(emigration to } y_k) = \frac{\mu_k}{\sum_{j=1}^{n} \mu_j}
\end{equation}

Ma and Simon [17] presented In these formulas
a represents an index of decision making
variable and δ represents a real number which
ranges from 0 to 1 and can occur randomly,
definitely, and in accordance with a relative
fitness $y_k$ and $y_j$. Emigration probability is done
through roulette-wheel selection as is shown in
Fig. 3 [16]. Conducted studies on biogeography-
based optimization showed that this method is
suitable for most of the issues.

**BBO Algorithm**

1: for each candidate solution $y_k$ do
2: for each candidate solution decision variable
   index $a$ do
3: use $\lambda_k$ to probabilistically decide whether to
   immigrate to $y_k$ (see Eq.(2))
4: if immigrating then

![Fig. 2. A Curve of Linear Migration of BBO [15]](image-url)
5: use \{ \mu \} to probabilistically select the emigrating candidate solution \( y_k \) (see Eq. (1))
6: \( y_k(a) = \delta y_k(a) + (1 - \delta) y_j(a) \)
7: end if
8: end for
9: probabilistically decide whether to mutate \( y_k \)
10: end for

Fig. 3. BBO Algorithm [16]

3. The Proposed Method
This part proposes a method for text summarization using the biogeography-based optimization method. In the proposed method, first pre-processing should be done on the input text. This function is done as follows:
1. Reading documents to ensure coherence among them.
2. Omitting additional characters such as \{\}, \], ...
3. Omitting unessential words such as at, in, on, and of ...
4. Finding the roots of the words and verbs used in the main text.
5. Separating words from each other and omitting repeated words.
6. Identifying the end of the sentences and separating the sentences from each other.
7. Calculating the number of words and sentences used in the main text.

Then the sentences extracted from the pre-processing step should be weighed, using a weighing method of TFIDF which is equivalent to term-frequency inverse document-frequency. Garsia and Ledeneva [4] presented, In the weighing method in Eq. (4) and Eq. (5), \( freq_{ij} \) represents the repetition number of \( i \) word in \( j \) sentence, \( freq_{ij} \) represents a frequency maximum of \( I \) word in \( j \) sentence, \( maxfreq_{ij} \) represents the number maximum of \( i \) word repetition in \( j \) sentence, \( N \) and \( n_i \) represent the number of sentences in an input text and the number of sentences, respectively. Then a weight of each word in sentence \( w_{ij} \) is calculated, using Eq. (6).

\[
tf_{ij} = \frac{freq_{ij}}{maxfreq_{ij}} \quad \text{(4)}
\]
\[
idf_{ij} = \log \frac{N}{n_i} \quad \text{(5)}
\]
\[
w_{ij} = \text{tf}_{ij} \cdot \text{idf}_{ij} \quad \text{(6)}
\]

After the sentences are weighed, a similarity matrix should be weighed, using Eq. (7). In a similarity matrix, sentences are compared based on their keywords and important words.

\[
sim(s_i, q) = \frac{\sum_{i=1}^{t} w_{ij} \cdot w_{iq}}{\sqrt{\sum_{i=1}^{t} w_{ij}^2 \cdot \sum_{j=1}^{t} w_{iq}^2}} \quad \text{(7)}
\]

Now, important and summarized sentences should be extracted from the main text, using a biogeography-based optimization method. The proposed method consists of a set of initial parameters based on Fig. 4 which should be valued. In this method, the number of habitats and the number of operation repetitions are considered to be 50 and 100, respectively. Then, the overall number of sentences, the number of summarized sentences, and a similarity matrix are considered as input parameters of the proposed method. Following the implementation of the method, sentences with high scores are selected and displayed as a summarized text.

the cost of each habitat in based optimization algorithm calculated based on its sentences. Following the calculation of the similarities of sentences, a similarity factor is obtained from Eq. (8) and Eq. (9).

\[
TRF_s = \frac{\max_{v \in \text{Summary}}(TR)}{s} \quad \text{(8)}
\]
\[
TR_s = \sum_{s \in \text{Summary}} \frac{\sim(s_i, q)}{s} \quad \text{(9)}
\]

In this case, \( TR \) represents a similarity mean in \( s \) summarization. \( TRF \) represents similarity factor, which is calculated based on \( TR \). Also, a maximum is calculated from all possible \( S \) summaries. \( TRF \) shows the extent to which a document summarization is similar to a document itself. In the summaries in which the sentences are related to the document, \( TRF \) is approximately 1, but in the summaries in which the sentences are not related to the document, \( TRF \) is approximately zero. \( Rs \) represents a readability factor of a summary with an amount of \( s \). Therefore, a readability factor RF can be obtained, using Eq. (10) and Eq. (11) which introduced by Qazvinian et al. [18].

\[
\text{Step 1: Initial amount of biogeography-based algorithm parameters}
\]
\[
\text{Step 2: Random assignment of sentences in habitats}
\]
\[
\text{Step 3: Calculation of immigration rate and emigration rate from Eq. (1) and Eq. (2)}
\]
\[
\text{Step 4: Investigating habitats based on cost function}
\]
Step 5: Updating the situation of habitats based on the best conditions
Step 6: If a final condition is maintained (finding the best sentences), a method would come to an end and important sentences would be shown. Otherwise, that person should return to step 4.

**Fig. 4. Proposed method with the use of BBO**

\[
RF_s = \frac{R_s}{\max_v R_i} \quad (10)
\]

\[
R_s = \sum_{0 \leq i < s} W(s_i, s_{i+1}) \quad (11)
\]

An expense function can be calculated using Eq. (12) and Eq. (13).

\[
C_s = \frac{\sum_{s_i \in S, s_j \in summarysubgraph} W(s_i, s_j)}{N_s} \quad (12)
\]

\[
CF_s = \frac{\log(C \times 9 + 1)}{\log(M \times 9 + 1)} \quad (13)
\]

In Eq. (12) and Eq. (13), CFs calculates the amount of sentence cohesion. A cohesion factor will make the existent sentences in a summary to show similar information. A readability factor of sentences shows that the first, second, and final summarized sentences are related to each other with high similarity. Also, in a cohesion factor of sentences, C represents a similarity mean among sentences in S summary, M represents the highest amount of sentence similarity, and Ns shows an overall amount of summarization.

**4. Simulation and Results of Investigation**

In an extractive method, the results of the study are investigated against four criteria. These four criteria are as follows:

1. Investigation based on a text quality
   This kind of investigation is done by a human being. A summarized text which is based on some defined indicators is given a score.
2. Investigation based on a Selection
   This kind of investigation is done based on sentence correspondence.
3. Investigation based on a Content
   This kind of investigation is done based on word correspondence.
4. Investigation based on a Duty

In this kind of investigation, a quality of a summarized text is measured based on people’s demands. In the proposed method, simulation is done based on the second method (Sentence or response). In this method, an extracted summary is compared with an ideal summary and an extracted summary is investigated against criteria like precision, recall, and score which can be seen respectively in Eq. (14), (15) and (16), which introduced by Abuobieda, Salim et al. [19].

\[
\text{precision} = \frac{\text{RelevantSentences} \cap \text{RetrievedSentences}}{\text{RetrievedSentences}} \quad (14)
\]

\[
\text{Recall} = \frac{\text{RelevantSentences} \cap \text{RetrievedSentences}}{\text{RelevantSentences}} \quad (15)
\]

\[
F\text{-Score} = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \quad (16)
\]

In Eq. (14), Precision is an intersection of extracted summarized sentences and an ideal summary of sentences divided by all the extracted sentences. In Eq. (15), Recall is an intersection of relevant sentences and retrieved sentences divided by all the relevant documents. In Eq. (16), Score is a statistical criterion which is a combination of precision and recall criteria and shows the score of final selected sentences in a summary of a text since calculation of these criteria is a little hard and time consuming. ROUGE automatic software is used for investigating these criteria. A language of this software is Perl, which includes different packages for the purpose of investigating a summarized text. This software studies the mentioned criteria and shows the results. Nine Doc standard documents of 2002 were used for the purpose of investigating the proposed method. The test results for documents with 400, 200, and 100 words were compared with GA [11], PSO [12], BFOA [13] algorithms. The results are displayed in Table 1, Table 2 and Table 3.

**4-1. Experiment**

In this experiment, Table 1 and the graph in Fig 5 show the comparisons between a genetic algorithm method and a biogeography-based optimization method on similar samples of 100 word documents. As it can be seen, precision, recall, and score in the proposed method show more improvement than those in the genetic algorithm method.
4-2. Experiment 2
This experiment is conducted to compare the proposed algorithm with genetic algorithm and biogeography-based optimization method on similar samples of 200 word documents. Table 2 and the graph in Fig. 6 show the results obtained for this experiment. As it is shown, precision, recall, and score in the proposed method performs better than the others algorithms.

4-3. Experiment 3
In this experiment Table 3 and the graph in Fig. 7 show the comparisons between a genetic algorithm method and a biogeography-based optimization method on similar samples of 400 word documents. As it can be seen, precision, recall, and score criteria in the proposed method show relatively more improvement than those in the genetic algorithm method.

**Fig. 5. Comparison Graph of BBO and GA Based on F-score in a Model of 100 – Words Documents**

**Table 1. Comparison of 100-word documents**

<table>
<thead>
<tr>
<th>DOC</th>
<th>Precision</th>
<th>Recall</th>
<th>F-score</th>
<th>Precision</th>
<th>Recall</th>
<th>F-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>d061j</td>
<td>0.19048</td>
<td>0.56604</td>
<td>0.28504</td>
<td>0.18619</td>
<td>0.58491</td>
<td>0.28247</td>
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<tr>
<td>d065j</td>
<td>0.8883</td>
<td>0.62000</td>
<td>0.15540</td>
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<td>0.17664</td>
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<tr>
<td>d067f</td>
<td>0.14014</td>
<td>0.53774</td>
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<td>0.53774</td>
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<tr>
<td>d070f</td>
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<td>0.19245</td>
<td>0.69000</td>
<td>0.16707</td>
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<tr>
<td>d073b</td>
<td>0.19291</td>
<td>0.50000</td>
<td>0.27841</td>
<td>0.20745</td>
<td>0.39796</td>
<td>0.27273</td>
</tr>
<tr>
<td>d075b</td>
<td>0.11154</td>
<td>0.53211</td>
<td>0.18442</td>
<td>0.09760</td>
<td>0.55963</td>
<td>0.16621</td>
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<tr>
<td>d079a</td>
<td>0.09792</td>
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<td>d085d</td>
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<td>d105g</td>
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<td>0.61000</td>
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Tab. 2. Comparisons of 200-word documents

<table>
<thead>
<tr>
<th>DOC</th>
<th>BBO</th>
<th>GA</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>Precision</td>
<td>Recall</td>
</tr>
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</tbody>
</table>

Fig. 6. Comparison Graph of BBO and GA Based on F-score in a Model of 200-words Documents

4-4. Experiment 4

In this experiment, Table 4 and the graph in Fig. 8 show the comparisons between genetic algorithm method Particle Swarm Optimization, Bacterial Foraging Optimization Algorithm and biogeography-based optimization method on similar samples of 400 word documents. As it can be seen, F-score criteria in the proposed method show the relative improvement compared to those in other methods.

Tab. 3. Comparisons of 400-word documents

<table>
<thead>
<tr>
<th>DOC</th>
<th>BBO</th>
<th>GA</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>Precision</td>
<td>Recall</td>
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</tr>
</tbody>
</table>
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\[d075b \ 0.45192 \ 0.55035 \ 0.49630 \ 0.43040 \ 0.62998 \ 0.51141\]

\[d079a \ 0.41242 \ 0.65258 \ 0.50545 \ 0.50928 \ 0.57981 \ 0.54226\]

\[d085d \ 0.38704 \ 0.55388 \ 0.45567 \ 0.36581 \ 0.49875 \ 0.42206\]

\[d105g \ 0.43130 \ 0.66488 \ 0.52320 \ 0.33427 \ 0.63539 \ 0.43807\]

Fig. 7. Comparison of BBO and GA based on F-score in a model of 400 –words Documents

5. Conclusion
In this article, different methods of text extractive summarization along with their advantages and disadvantages were discussed. Then, a biogeography-based optimization method was proposed (Fig. 4) and used in a text extractive summarization. Next, the ways in which the short sentences are selected and scored were presented. Finally, a proposed method was tested with 9 sets of doc standard documents of 2002. These documents were those of 100 (Table 1 and Fig. 5), 200 (Table 2 and Fig. 6) and 400 (Table 3 and Fig. 7) words. Then, the test results were analyzed using ROUGE software. The results of four tests showed the superiority of the proposed method compared to other methods in terms of efficiency (Table 4 and Fig. 8).

Tab. 4. Comparisons of 400-word documents

<table>
<thead>
<tr>
<th>DOC</th>
<th>BBO F-score</th>
<th>GA F-score</th>
<th>PSO F-score</th>
<th>BFOA F-score</th>
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Fig. 8. Comparison Graph of BBO, PSO, BFOA and GA based on F-score in a model of 400-word Doc

References


