IDENTIFYING STUDENTS' SUMMARY WRITING STRATEGIES USING SUMMARY SENTENCE DECOMPOSITION ALGORITHM

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ABSTRACT

Summary writing is one of the important skills taught in schools. A summary is a condensed version of an existing text. Its production differs from other types of writing where it requires the use of specific strategies. Most research on summary assessments focused on the end product of summary writing instead of its process. Research has shown that lack of strategic skills is a cause of students' difficulties in writing good summaries. There are a few systems available to assist teachers in assessing students summaries based on content and style. But virtually none have been developed to assess the process particularly in identifying the strategies used. To address this need, we propose an algorithm based on summary sentence decomposition to identify students' strategies in summary writing. We first analyzed experts' written summaries, extracted the strategies used in the summaries, formulated a set of heuristics rules to define the strategies and finally transformed the rules using position-based method into summary sentence decomposition algorithm (SSDA). For evaluation, we measured the algorithm's functionality in identifying the different strategies. We also compared its performance against human experts. The results based on 168 summary sentences indicate that the algorithm successfully identified these syntax level strategies: deletion, sentence combination, copy-paste, syntactic transformation and sentence reordering. In comparison to human performance, the algorithm's performance closely matched that of human with 94% accuracy in identifying the syntax level strategies. For future work, the algorithm will be extended to identify the semantic level strategies, diagnose the strategies used and provide constructive feedback.

Keywords : summary writing, summarizing strategies, heuristic rules, position-based method, summary sentence decomposition algorithm

1.0 INTRODUCTION

One of the important skills taught in schools to help improve comprehension ability is summarization. This skill involves a few main processes such as reading and understanding the content of a text, identifying the most important information in the text, and producing a shorter version of it called summary. Summary writing is included in schools' syllabus to assess students' understanding and ability in summarizing texts. It is also a vital skill required by students to navigate learning at tertiary level to effectively support other learning skills needed at that level such as note taking, extensive reading and writing.

As opposed to other types of writing such as writing a story or a report, the production of a summary is dependent on existing texts [1]. It does not require basic planning of content and structure by generating new ideas since the operations are based on ideas generated from the original text. It depends on the reader's decision on what to include, what to eliminate, how to organize information and how to ensure that the summary retains the meaning of the original text. However, to produce a good summary requires a full understanding of the original text. It involves recursive reading-writing activities between the text and the summary being produced [2]. In summary writing, there are essential summarizing strategies to produce adequate summaries and students are required to use these strategies efficiently to write good summaries.

Summarization is a difficult skill particularly for novices or students. Traditional way of teaching and learning summary writing is not conducive to helping students improve their summarizing skills because of its emphasis in the final product which is the quality of the summary instead of the process which is the strategies used to produce that summary. Research has shown that lack of strategic skills is a cause of students' difficulties in writing good summaries [3]. This is also indicated in the preliminary findings from the analysis of 56 high school students' summaries where students who used a wide range of summarizing strategies obtained higher marks compared to those who did not [4]. Less attention is given to the process of summary writing as it requires teachers to identify the strategies used by students in their summaries. The process of identifying the strategies is time consuming and requires lots of effort. There are no standard methods or tools for easy and fast identification of these strategies for teachers. Hence the task of reviewing the summaries and giving individualized feedback on the strategies or lack of strategies used is often seen as a burden. This hampers improvement in students' summarizing skills.

A few systems have been developed to evaluate summaries automatically (e.g. as in [5], [6], [7] and [8]). For example, *Summary Street®* [5][6] is a computer-based assessment system that provides an environment where students can get feedback about the content of their written summary. It also gives immediate feedback on the length of the summary, the redundancy of the sentences in the summary, the relevancy of the summary sentences to the topic and plagiarism. Similar to *Summary Street*, *LEA* [7] gives feedback on the coherence, content coverage and cohesion, the use of language and adequacy of the summary. Another example, *Summary Assessment System* [8] offers feedback on the content coverage using ensemble approach. The differences between Summary Street, LEA and Summary Assessment System are summarized and presented in Table 1 below.

Table 1: Differences between tools in summarization assessment

System	Method used	Assessment Criteria	Feedback
Summary Street	Latent Semantic Analysis (LSA)	Content	Content coverage, length, redundancy, relevancy and plagiarism.
LEA	Latent Semantic Analysis (LSA) NLP tools (lemmatiser, spell checker)	Content / style	Coherence, content coverage, cohesion, language and adequacy.
Summary Assessment System	Ensemble approach using LSA and n-gram	Content	Content coverage.

Although previous works have contributed towards the development of the summarization assessment systems, their focus is only on the content of the summary viz. the summary has to be concise, include only main ideas and avoid redundancy. No literatures have been found at the time of writing this paper on any automated summarization assessment systems for identifying students' summarizing strategies. Hence, we propose an algorithm to identify the summary writing strategies used by students called summary sentence decomposition algorithm or SSDA. The algorithm is derived from a set of heuristic rules formulated from the decomposition of experts' summary sentences using position-based method. The remainder of this paper is organized as follows. Section 2 describes the heuristic rules, Section 3 presents the algorithm, Section 4 discusses the experimental results and Section 5 concludes the paper.

2.0 HEURISTIC RULES FOR THE IDENTIFICATION OF SUMMARIZING STRATEGIES

In 1983, Brown & Day have identified several summarization rules or strategies to produce a summary which are deletion, generalization, selection of topic sentence and invention [9]. However, the description pertaining to each rule is vague and ill-defined. For example, the process of the deletion rule is described as follows:

Rule	**Process**
Deletion	*Deletes unimportant information from the original text*

In this rule, the term *'unimportant information'* is very subjective and quite vague thus converting such ill-defined rule into an algorithm is a difficult task. To develop a system that can automatically identify students' strategies used in summary writing, each summarizing strategy must be defined by measurable and precise rules. To produce these measurable and precise rules, human skills in summary writing need to be analyzed.

Experts produce better summaries than students and they employ a number of summarizing strategies to produce good summaries. Hence, to identify each strategy, we collected samples of experts' summary sentences and analyzed the sentences to determine the characteristics of each strategy. The results of the analysis are then used to formulate a more detailed and precise rules.

Our study on experts' summaries attempts to answer these questions:
Given an expert's summary sentence:

- *Is the summary sentence produced from the sentences of the original text?*
- *What are the summarizing strategies used by experts to produce the summary sentence?*
- *How can each summarizing strategy be identified?*

2.1 Material
A text with factual information and personal observations, extracted from an article in Readers Digest Canada 2004 entitled *Getting a Handle on Dyslexia* was used in this study. This article is about children with dyslexia and how to handle it. It contains 15 paragraphs and 1177 words.

2.2 Participants and procedure
Participants from the following three categories and considered as experts were used in this study:

1) English teachers with experiences in teaching summary writing in secondary schools;
2) Lecturers who are experienced in using the summarizing skills in their teaching;
3) Final year English language and literature students from School of Humanities, University Sains Malaysia.

They were asked to write a summary of the above article. 10 samples were collected from 10 experts and document analysis was used to analyze these summaries.

2.3 Analysis
In this analysis, summary sentence decomposition method was used to determine if the sentences were produced from the original text and how they were constructed since the production of a summary is dependent on existing text. The steps to identify the summarizing strategies used by the experts are shown in Fig. 1.

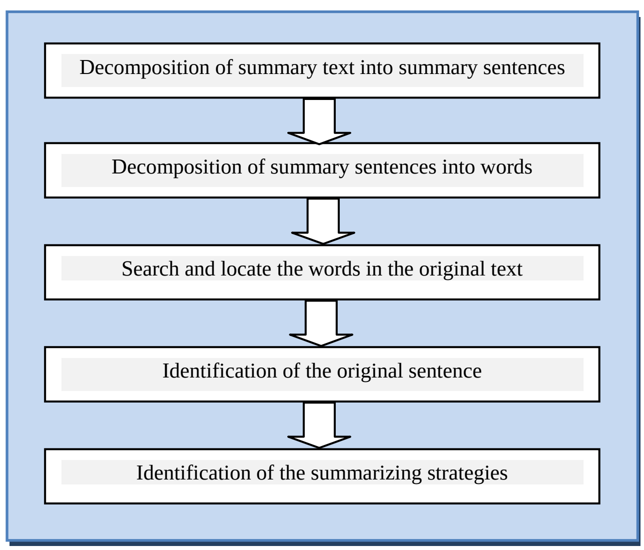

Fig. 1: Steps to identify the experts' summarizing strategies

We first decomposed the experts' summary text into summary sentences. These sentences were then separated into words as depicted in the second step in Fig. 1. Next, we searched for the words in the original text and noted their locations in the original text if found. The locations of the words in the original text will reveal the original sentence corresponding to the summary sentence. Lastly, we analyzed the relationship between each summary sentence and its corresponding original sentence to identify the summarizing strategies used by the experts to produce the summary sentence. To identify the experts' strategies, we refer to the basic summarization rules [9] and produced the following guidelines:

- *deletion – if the summary sentence is shorter than the corresponding original sentence.*
- *sentence combination – if the summary sentence is produced from more than one corresponding original sentences.*
- *generalization – if a word or a phrase in the summary sentence refers to or replaces a list of items in the corresponding original sentence*
- *paraphrase – if a word in the summary sentence is a synonym of a word in the corresponding original sentence*
- *topic sentence selection – if the summary sentence or its meaning can be found at the beginning or the end of a paragraph in the original text*
- *invention – if more than 75% of the summary sentence contain words not found in the original text and the meaning of the original text is retained.*

2.4 Results

The analysis of the 10 experts' summaries revealed that they had used 6 types of summarizing strategies which are deletion, sentence combination, generalization, paraphrasing, topic sentence selection and invention in addition to two operations which are syntactic transformation and sentence reordering. We called the latter as operations since they do not belong to any of the basic summarizing strategies. These strategies and operations can be categorized into either the syntax or the semantic level group. Syntax level strategies involve reusing or reordering of the words and sentence in the original text to produce the summary sentence while the semantic level strategies involve the meaning of the words or sentences. Deletion, sentence combination, syntactic transformation and sentence reordering can be classified as the syntax level group while the others belong to the semantic level group. The analysis was syntactical as identification of the strategies for summary sentences was based on the positions of the words in the original text. As such, this position based method is only applicable to identify syntax level strategies which are deletion, sentence combination, syntactic transformation and sentence reordering. These summarizing strategies and operations were then formalized into a set of heuristic rules to identify students' summarizing strategies as shown in Table 2. We also formulated the heuristic rule for the copy-paste method as it is a common method used by students in summary writing [4].

Table 2: A set of heuristic rules for the identification of summarizing strategies and operations

Strategy / Operation	Heuristic Rules
Deletion	A summary sentence is produced using deletion strategy if: • its number of words is less than the number of words in the corresponding original sentence, • it contains phrases, where all the words in each phrase: **i.** come from the same sentence in the original text **ii.** are close to each other in the original sentence and the average distance of those words in the original sentence is between 1.0 and 3.0.
Sentence Combination	A summary sentence is produced using sentence combination strategy if: • it contains a combination of phrases from two or three sentences in the original text, • the average distance of these corresponding original sentences where those phrases come from is between - 2 and 3, • the combination of those phrases involves the use of conjunction words or commas.
Syntactic Transformation	A summary sentence is produced using syntactic transformation operation if, • it contains a phrase and all the words in the phrase come from the same sentence in the original text, • the order of the words in the phrase is a reverse of its relative order in the corresponding original sentence.
Sentence Reordering	A summary sentence is produced using sentence reordering operation if: • it involves sentence combination strategy, • the order of the combined phrases in the summary sentence is different from or a reverse of its relative order in the corresponding original sentences
Copy-paste	A summary sentence is produced using copy-paste if, • the number of words in the summary sentence is the same as the number of words in the corresponding original sentence, • more than 90% of the words in the summary sentence are from a single sentence in the original text, • the position of the words in the summary sentence and in the corresponding original sentence is the same.

3.0 SUMMARY SENTENCE DECOMPOSITION ALGORITHM

The heuristic rules described in the previous section are translated into an algorithm that can be used to identify student summarizing strategies. The algorithm is called *summary sentence decomposition algorithm* (SSDA) since the summary sentences are decomposed into words and position-based method is used to locate the positions of the words in the original text. Summary sentence decomposition is a process to determine whether a summary sentence is generated from the original text and to identify the reused words in the original text [10].

To identify students' summarizing strategies using summary sentence decomposition, the algorithm needs to fulfill the following requirements :

Given a summary sentence, determine

- *the words in the summary sentence that can be found in the original text,*
- *the locations of the words in the original text,*
- *the best combination of summary sentence words' locations used to represent the summary sentence,*
- *the original sentences used to produce the summary sentence,*
- *the construction method of the summary sentence from the original sentence.*

The algorithm comprises five major processes which are shown in the shaded boxes in Fig. 2.

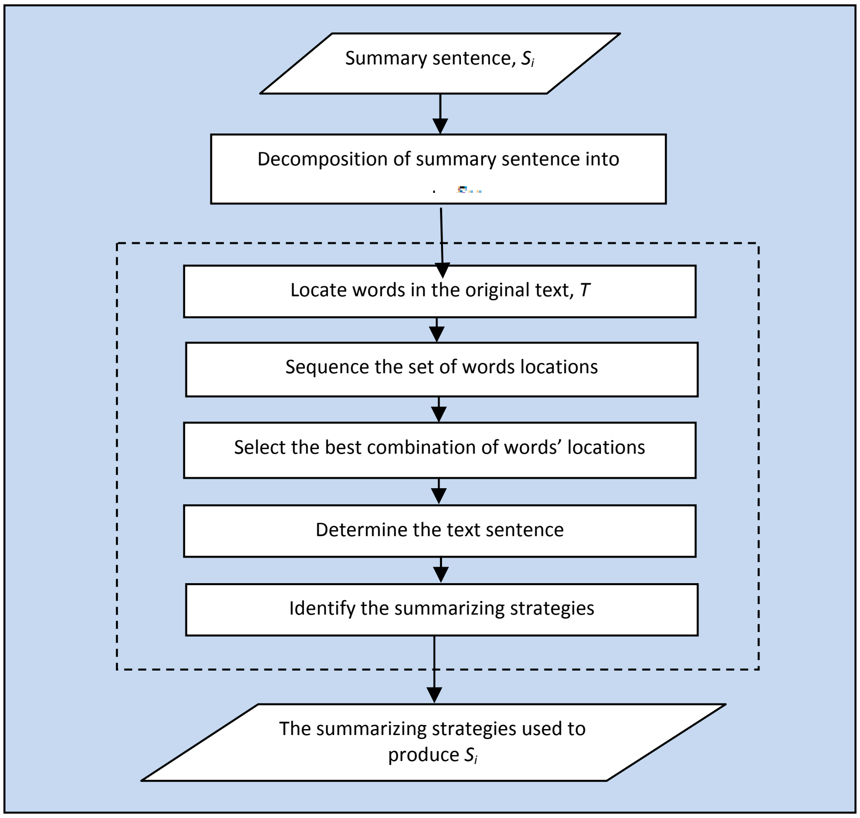

Fig. 2 Processes in SSDA

The details on each process are as follows:

1. Locate words in the original text
It is a process to determine whether the words in the summary sentence exist in the original text and to locate the positions of these words in the text using position-based method.

A summary text comprises a sequence of sentences which in turn comprises a sequence of words. If T is a text consisting of m sentences $\{t_i\}$, t_i the i^{th} sentence where $i = 1, 2, 3, \ldots m$, then T can be written as:

$$T = \{t_i\}; \quad i = 1, 2, 3, \ldots\ldots, m$$

Hence, for sentence t_i, comprising a string of n_i words, t_{ij} where $j = 1, 2, 3, \ldots n_i$, then t_i, can be written as,

$$t_i = \{t_{ij}\}; \quad j = 1, 2, 3, \ldots\ldots, n_i \quad where\ n_i\ varies\ for\ different\ i.$$

$$\therefore T = \{t_{ij}\}; \quad i = 1(1)m \quad j = 1(1)n_i \qquad (1)$$

Similarly for summary text, S, where every summary is a sequence of k summary sentences s_i and every summary sentence, s_i, comprises a string of l_i words,

$$S = \{s_i\}; \quad i = 1, 2, 3, \ldots\ldots, k$$

$$s_i = \{s_{ij}\}; \quad i = 1, 2, 3, \ldots\ldots, k \quad j = 1, 2, 3, \ldots\ldots, l_i; \quad l_i - words\ position\ in\ s_i$$

$$\therefore S = \{s_{ij}\}; \quad i = 1(1)k \quad j = 1(1)l_i \qquad (2)$$

The summary sentence is analyzed using the *position-based method* where a word in original text, T, can be represented as t_{ij}. i and j indicate the location of the word where i is the sentence position in the text and j is the word position within the sentence. The location of the word in the text can be written as (i, j). If a word, s_{ij}, is found in text T, and that word is t_{kl}, then,
$s_{ij} \equiv t_{kl}$

For example, given a summary sentence and the original text below :

<u>Summary sentence</u>
I fell into the ocean.

<u>Original text</u>
[1] I watched in horror as my boat floated out of reach. [2] I was determined not to lose it. [3] In one huge step, I stretched my arm as far as it could go and tried to grab the boat. [4] Unfortunately, I missed and fell into the ocean, forgetting that I could not swim. [5] I was enveloped in seawater. [6] Panic-stricken, I paddled and kicked hard, trying to remain above the ocean.

The words of the summary sentence are found in the original text and their locations in the text are as shown in Table 3.

Table 3 Location of the summary sentence words in the original text

Summary Sentence	***Original text***		
Words	***Sentence position, i***	***Word position, j***	***(i, j)***
I	1	1	(1, 1)
	2	1	(2, 1)
	3	5	(3, 5)
	4	2	(4, 2)
	4	11	(4, 11)
	5	1	(5, 1)
	6	2	(6, 2)
fell	4	5	(4, 5)
into	4	6	(4, 6)
the	3	19	(3, 19)
	4	7	(4, 7)
	6	11	(6, 11)
ocean	4	8	(4, 8)
	6	12	(6, 12)

2. Sequence the set of words' locations
For every word in the summary sentence that is found in the original text, the location of that word in the text is noted. These words' locations are listed together to construct a combination of words' locations, *cwl,* of the summary sentence as shown in Fig. 3. Some words may occur more than once in the original text, and probably in different sentences. Hence, each summary sentence has a set of *cwl* found in the original text.

To obtain the total number of combinations, the number of times each word occurs in the original text is multiplied with each other. This method could produce a large number of possible combinations which increases the number of search spaces and consequently making the process of selecting the best *cwl,* time consuming. Using the example of the summary sentence above, there will be 7 x 1 x 1 x 3 x 2 = 42 possible combinations. To reduce the number of search space, we propose a new mechanism to find the optimum set of *cwl* for a summary sentence called *sequencing*. It is a process which combines the words' locations according to the sentence positions of the first word of the summary sentence found in the text. The reason for doing so is because a phrase usually comes from the same sentence in a text. Hence, for each set of *cwl*, their sentence positions should be the same.

The algorithm for the sequencing process is as follows:

For each word location of the first summary word found in T
For each word location of subsequent summary words found in T
Compare their sentence positions
If the sentence positions are the same
Combine the word locations into a list

For example, there are 7 combinations of *cwl* for the summary sentence, *"I fell into the ocean"* and the process of sequencing is illustrated in Fig. 3.

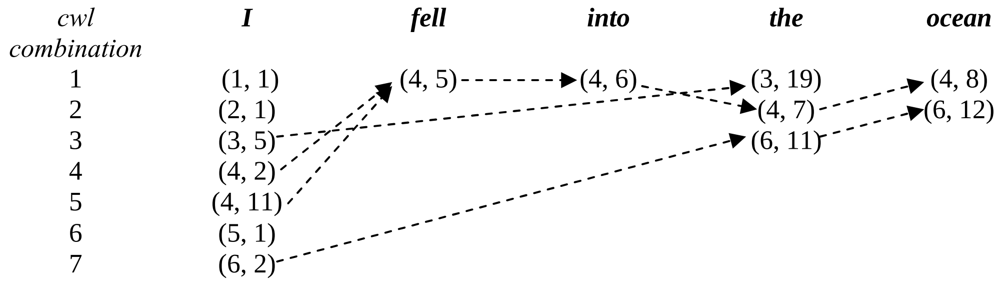

Fig.3 A set of *cwl* in *T* using sequencing

Let $cwl_k(i)$ be a list of combination where *i* is the sentence position of the words in the original text and $k = 1, 2, 3, \ldots, n$ where *n* is the total number of combinations. Hence, a set of combinations of the words' locations are as follows, where the total number of combinations has been reduced to only 7 combinations:

$$
\begin{aligned}
cwl_1(1) &= \{(1,1)\} \\
cwl_2(2) &= \{(2,1)\} \\
cwl_3(3) &= \{(3,5),(3,19)\} \\
cwl_4(4) &= \{(4,2)(4,5)(4,6)(4,7)(4,8)\} \\
cwl_5(4) &= \{(4,11)(4,5)(4,6)(4,7)(4,8)\} \\
cwl_6(5) &= \{(5,1)\} \\
cwl_7(6) &= \{(6,2)(6,11),(6,12)\}
\end{aligned}
$$

As a conclusion, sequencing is a process used to reduce the total number of combinations, which in turn, reduces the number of search space for selecting the best *cwl*.

3. Select the best combination of words' locations (cwl)

The third process in SSDA is to determine and select the best *cwl* from the list of combinations pertaining to the summary sentence. The best *cwl* is the one that surpassed all the other *cwl*s according to the criteria defined in the heuristic rules. Since each criterion is defined based on the proximity of words and sentences, each rule defining a strategy can easily be differentiated from the others hence the strategy can be identified. The threshold for each category of the word and sentence proximity index was determined from the analysis of the experts' summaries. The process to determine the best *cwl* is translated into an algorithm as follows:

For each $cwl_k(i)$,

i. *Let n be the number of words in* $cwl_k(i)$.
ii. *Let* m *be the number of words in* s_i.
iii. *Compare the number of words in* s_i, **m**, *with the number of words in each* $cwl_k(i)$, **n**, *and calculate the difference between them where,*

$$diff = m - n$$

$$(if\ diff = 0\ then\ m = n;\ all\ the\ words\ in\ s_i\ are\ found\ in\ that\ cwl_k)$$

iv. *Calculate the word proximity index,* φ *, for each* $cwl_k(i)$ *using the following equation where,*

$$\varphi = \sum_{y=1}^{n-1} (j_{y+1} - j_y) / (n-1)$$

where,

n : *the number of words*

j_y : *the word position of the first word*

j_{y+1} : *the word position of the second word*

v. *Categorize each* $cwl_k(i)$*, to word category,* w_{cat}*, according to their index,* φ *as shown below:*

- $If\ 0 < \varphi \leq 1, \quad then\ w_{cat} = 1$
  (The words are in adjacent positions)
- $If\ 1 < \varphi \leq 3, \quad then\ w_{cat} = 2$
  (The words are close to each other and their order is the same as in the original sentence).
- $If\ -3 \leq d < 0, \quad then\ w_{cat} = 3$
  (The words are close to each other but the order of the words is a reverse of their order in the original sentence, as in the case of syntactic transformation)
- $If\ \varphi > 3\ or\ \varphi < -3, \quad then\ w_{cat} = 4$
  (The words are far from each other)

vi. *Select the* $cwl_k(i)$ *with the smallest value for both* w_{cat} *and* $diff$ *as the best cwl in* T *used to produce the summary sentence. Then, extract the sentence position of the best cwl,* i_k.

In most cases, there is only one phrase in a summary sentence. However, there are a few cases where there is more than one phrase. A summary sentence with multiple phrases is usually produced from several different sentences of the original text, as in sentence combination cases. Since the phrases in the summary sentence are constructed from more than one sentence of the original text, the proximity index between the sentences needs to be considered. The process of calculating the sentence proximity index is described as follows:

i. *Calculate the sentence proximity index,* δ *, of the sentence of the first phrase and the sentence of the subsequent phrase in the summary sentence using the following equation :*

$$\delta = i_2 - i_1 \qquad \textit{where,}$$

i_1 : the position of the first sentence

i_2 : the position of the second sentence

ii. *Categorize the cwl to sentence category,* s_{cat}*, according to the their index,* δ *:*

- $If\ \delta = 1, then\ s_{cat} = 1$
  (The phrases come from ***adjacent*** *original sentences and the phrases' order is the same as the order of the respective sentences in the original text)*
- $If\ 1 < \delta \leq 3, then\ s_{cat} = 2$
  (The phrases come from original sentences that are ***near*** *each other and the phrases' order is the same as the order of the respective sentences in the original text))*
- $If\ -3 \leq \delta < 0, \quad then\ s_{cat} = 3$
  (The phrases come from original sentences that are ***adjacent*** *or* ***near*** *to each other; and the order of the phrases is a reverse of the order of the respective sentences in the original text)*
- $If\ \delta > 3\ or\ \delta < -3, then\ s_{cat} = 4$
  (The phrases come from original sentences that are ***far*** *from each other)*

iii. *Select the* $cwl_k(i)$ *with the smallest value of* w_{cat} *and* s_{cat} *to be the best cwl in T used to produce the phrases in the summary sentence.*

4. Determine the text sentence

This is a process to determine the sentences of the original text that were used to produce the summary sentence. In the algorithm, the process is defined as follows:

$If\ cwl_b(l)_i\, b \in (1, 2, \ldots, k)\ is\ the\ best\ cwl\ then$

the sentence at position i *in the corresponding sequence in T is selected as the original sentence used to produce the summary sentence.*

5. Identify the summarizing strategies

The final process in the algorithm is to identify the summarizing strategies that are used to produce the summary sentence. This process involved the use of the heuristic rules formulated in Table 2, the number of words in the best *cwl* and in the original sentence and the proximity index of the words and sentences. In general, the comparative result between the number of words in the best *cwl* and the one in the original sentence will largely determine the different strategies. For example, if the number of words in the best *cwl* is less than the one in the original sentence, the strategy used to construct the summary sentence would be deletion. However, depending on the value of w_{cat} , the summary sentence could also be a result of applying syntactic transformation operation. On the other hand, if the number of words in the best *cwl* is equal to that in the original sentence, the strategies used could either be copy-paste or syntactic transformation depending on the w_{cat} value. If the number of words in the best *cwl* is neither equal nor less than the one in the original sentence, then the strategies used will be either sentence combination or sentence reordering depending on the s_{cat} value. The various conditions can be grouped into 9 categories. The way these conditions are written as an algorithm is shown in Fig 4 and the description of each category in relation to the strategies is in Fig 5.

$IF\ (h < l)\ AND\ (w_{cat} = 1)\ THEN$
Category 1
$IF\ (h < l)\ AND\ (w_{cat} = 2)\ THEN$
Category 2
IF (h < l) AND $(w_{cat} - 4)\ THEN$
Category 3
$IF\ (h = l)\ AND\ (w_{cat} = 3)\ THEN$
Category 4
$IF\ (h < l)\ AND\ (w_{cat} = 3)\ THEN$
Category 5
$IF\ (h = l)\ AND\ (w_{cat} = 1)\ THEN$
Category 6
$IF\ (s_{cat} = 1)\ OR\ (s_{cat} = 2)\ THEN$
Category 7
$IF\ (s_{cat} = 3)\ THEN$
Category 8
$IF\ (s_{cat} = 4)\ THEN$
Category 9

where,
h - the number of words in the best cwl
l - the number of words in the original

Fig.4 Conditions to determine the categories

Category 1:
The summary sentence is produced using Deletion strategy and the words are in adjacent positions
Category 2:
The summary sentence is produced using Deletion strategy and the words are close to each other and retain their order
Category 3:
The summary sentence is produced using Deletion strategy and the words are far from each other
Category 4:
The summary sentence is produced using Syntactic transformation
Category 5:
The summary sentence is produced using Deletion strategy & Syntactic transformation
Category 6:
The summary sentence is produced using Copy-paste
Category 7:
The summary sentence is produced using Sentence Combination strategy and the text sentences are in adjacent positions
Category 8:
The summary sentence is produced using Sentence Combination strategy & Sentence Reordering
Category 9:
The summary sentence is produced using Sentence Combination strategy but the text sentences are far from each other

Fig.5 The different categories of strategies

The final output of the algorithm is the summarizing strategies used to produce the summary sentence. To implement the algorithm, we have chosen LISP considering the features of that language for implementing AI tools and models particularly those involving text processing. An example of the output after executing this algorithm is shown in Fig. 6.

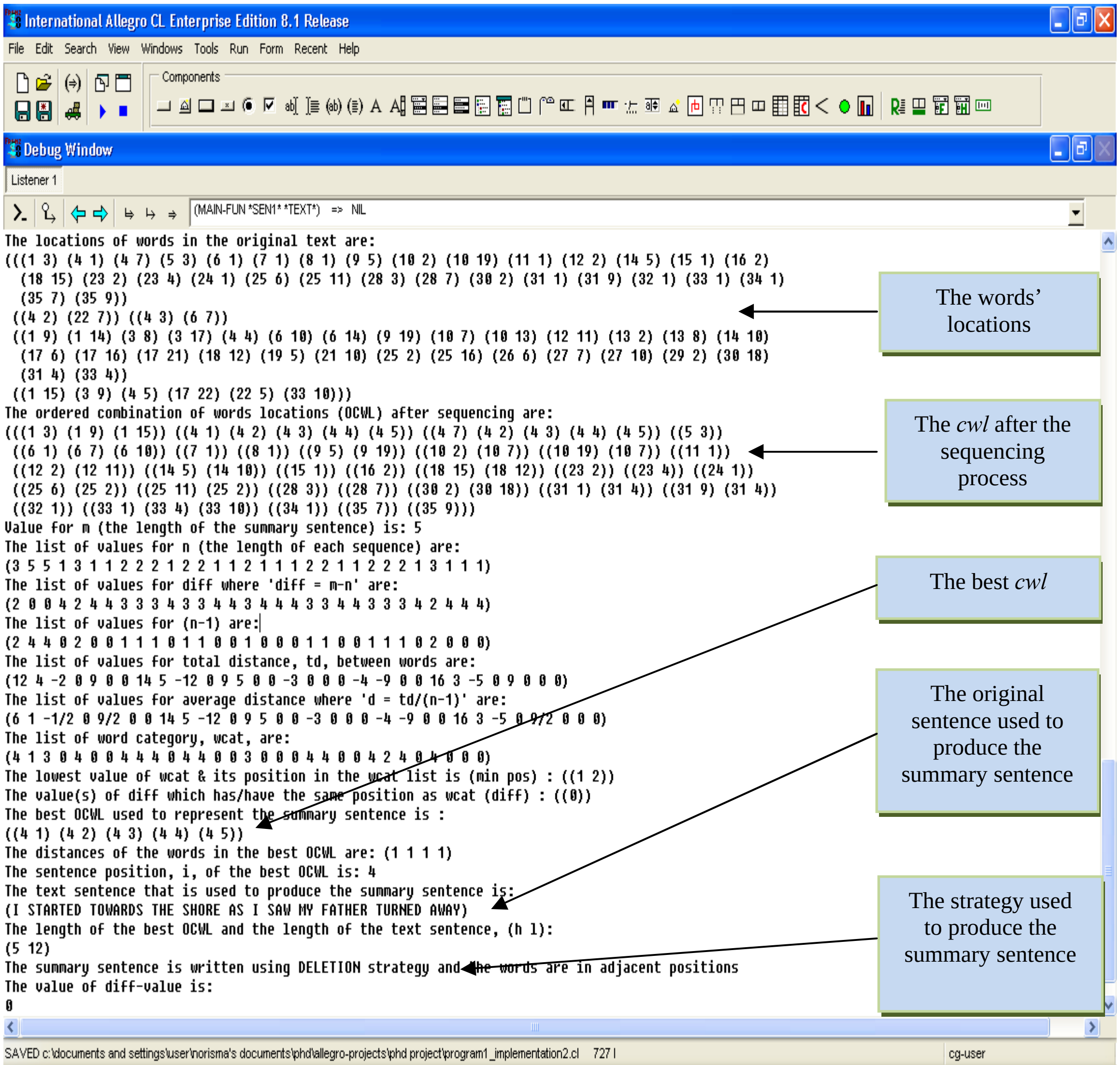

Fig. 6 Output of each process in the algorithm

4.0 EXPERIMENTAL EVALUATIONS

To evaluate our algorithm, we carried out two experiments using 20 secondary school students' summaries. In the first experiment, we evaluated the functionality of the algorithm in identifying the strategies and operations. In the second experiment, we measured the performance of the algorithm against human judgment.

4.1 Functionality of the Algorithm

The first experiment examined the ability of the algorithm to perform the task of identifying the summarizing strategies. We employ the simplest argument that if the algorithm is able to identify the summarizing strategies in each summary sentence, then it has the ability to perform the task. A total of 20 students' summaries were collected and decomposed by SSDA into 168 summary sentences.

The algorithm successfully identified the deletion, sentence combination and copy-paste strategies from the 168 summary sentences. In addition, it also identified the two operations: syntactic transformation and sentence reordering.

The results of the experiment are shown in Table 4. Each student's summary consists of different number of summary sentences. The dotted ellipse in Table 4 indicates that Summary 3 comprises 10 sentences where 8 of the sentences were constructed using the deletion strategy and two other sentences were the result of using sentence combination and another 2 from the copy-paste method. The student also used syntactic transformation and reordering to construct his summary sentences. The results provide evidence that the algorithm is able to identify the students' summarizing strategies using the position-based method.

Table 4. Summarizing strategies identified by SSDA

Summary	No. of summary sentences	Strategies			Operations	
		Deletion	Sentence Combination	Copy-paste	Syntactic Transformation	Sentence Reordering
1	9	9	3	0	4	0
2	8	8	5	0	4	0
3	10	8	2	2	3	1
4	7	7	5	0	4	0
5	10	10	6	0	3	1
6	8	8	3	0	3	0
7	9	9	5	0	1	0
8	9	9	7	0	4	0
9	7	7	4	0	3	0
10	8	8	7	0	0	1
11	11	11	4	0	4	1
12	11	11	2	0	3	0
13	6	5	4	1	0	1
14	7	7	3	0	0	0
15	6	6	5	0	0	0
16	8	7	4	1	0	0
17	11	11	6	0	1	1
18	10	10	3	0	0	0
19	5	4	2	1	0	0
20	8	8	7	0	1	0

4.2 Performance of the Algorithm

The second experiment is to gauge the performance of our algorithm in identifying the summarizing strategies against human expert judgments. The evaluation focuses on two major factors:

i. Precision and Recall
ii. Accuracy

i. Precision and Recall
Precision is used to evaluate the proportion of candidate items (the strategies identified by SSDA) that the SSDA correctly identified and recall is used to evaluate the proportion of the reference items (the summarizing strategies identified by human) that the SSDA identified.

The experiment was conducted using the same set of 20 summaries with the involvement of two experts (English teachers). Each expert was given 10 summaries which were decomposed into summary sentences. The experts were then instructed to identify the summarizing strategies used by students in each summary sentence. They were given two weeks to perform the task and the results were collected after the completion of the task. We compared the summarizing strategies identified by SSDA with those identified by these experts. We then used *Precision* and *Recall* measures to compare the performance of our algorithm with the human judgment. The precision and recall were computed as follows:

$$Precision = \frac{A}{A + X}$$

$$Recall = \frac{A}{A + Y}$$

where,

A - *number of the summarizing strategies exactly identified by SSDA and experts*
X - *number of summarizing strategies identified by SSDA only*
Y - *number of summarizing strategies identified by experts only*

The algorithm achieved an average of 78% precision and 72% recall for 20 summaries. It did not achieve high percentage (> 85%) for the precision and recall when compared to expert judgment due to the following reasons:

a. The algorithm failed to identify semantic level strategies which are paraphrase, generalization, topic sentence selection and invention. As an example, it did not find any association between the word *'fruits'* in the summary sentence and a group of words *'oranges, tomatoes and apricots'* in the original text. The experts, on the other hand, associated that substitution with the generalization strategy. However, this limitation is understandable since the algorithm is not designed to find those strategies related to semantics.
b. The algorithm could identify two operations that were used to construct summary sentences namely syntactic transformation and sentence reordering. The experts, however, did not identify such operations as these operations are not considered as summary writing strategies. Moreover, they were not instructed to identify such operations. Hence, similar to the former situation, this contributed to the reduced percentage.

ii. Accuracy

Another way to evaluate the performance of the algorithm is by assessing its accuracy in identifying syntax level strategies since the position- based method is applicable to these syntax level strategies only: deletion, sentence combination and copy-paste. We focused only on those three strategies and ignored the others for more accurate comparison. In this experiment, we used the same set of 20 summaries for the evaluation. For each summary, we counted the number of summary sentences which have exact experts and SSDA identified strategies as shown in the rightmost column, labeled *y*, in Table 5. For instance, summary 2 consists of 8 sentences and both the experts and SSDA identified the same strategies used to construct each of the 8 sentences. In the case of summary 1 which has 9 sentences, the strategy identified for 1 of the sentences is different between the experts and SSDA but both identified the same strategies used for the other 8 sentences.

Table 5. Experts and SSDA identified strategies

		Identified by experts	Identified by experts	Same identification by experts and SSDA
Summary	**Number of summary sentences**	**Number of summary sentences constructed from semantic level strategies only [x]**	**Number of summary sentences constructed from syntax level strategies [z]**	**Number of summary sentences constructed from syntax level strategies [y]**
1	9	0	9	8
2	8	0	8	8
3	10	1	9	9
4	7	0	7	6
5	10	0	10	10
6	8	0	8	6
7	9	2	7	7
8	9	1	8	7
9	7	0	7	7
10	8	1	7	6
11	11	0	11	11
12	11	0	11	10
13	6	1	5	5
14	7	0	7	6
15	6	0	6	6
16	8	0	8	7
17	11	4	7	7
18	10	0	10	10
19	5	0	5	5
20	8	1	7	7
Total	**168**	**11**	**157**	**148**

We then summed up the number for all the 20 summaries and calculated the accuracy for identifying the three strategies as follows:

$$Accuracy = \left(\frac{y}{z}\right) \times 100\%$$

$$\therefore Accuracy = \left(\frac{148}{157}\right) \times 100\%$$

$$= 94\%$$

SSDA performance in identifying syntax level strategies as compared to humans is quite high with 94% accuracy. The position-based method used in the algorithm aptly represents the heuristic rules that define those strategies which were based on the physical structure of words and sentences of the original text. A perfect accuracy is difficult to achieve due to factors relating to differences between what humans refer to and what the algorithm relies on in detecting the strategies. The human definition and understanding of what characterizes a strategy, say a deletion or copy-paste might be different from the ones defined in the rules of that strategy as used in the algorithm. Additional factors like the use of threshold values for the proximity index of the words and sentences to determine the W_{cat} and S_{cat} values might also be different or maybe non-existent to humans.

5.0 CONCLUSIONS

In this paper, we proposed a summary sentence decomposition algorithm, SSDA, to identify the strategies used by students in summary writing. SSDA was developed based on the heuristic rules formulated from the results of analyzing experts' written summaries. The set of heuristic rules defined were for these syntax level strategies and operations: deletion, sentence combination, copy-paste, syntactic transformation and sentence reordering.

For the evaluation of the algorithm, two experiments were conducted using 20 students' summaries. The first experiment evaluated the capability of the algorithm in identifying the strategies used to construct the summaries while the second one measured the performance of the algorithm against human judgment.

The results of the first experiment indicated that the algorithm could identify the syntax level strategies and operations that students used in their summaries. The results of the second experiment showed that the performance of the algorithm closely matches 88% that of human when identifying strategies involving both semantic and syntax levels. In identifying syntax level strategies only like deletion, sentence combination and copy-paste, the algorithm performed better with 94% accuracy.

For future work, the algorithm would be extended to identify the semantic or deep level strategies normally used by experts such as paraphrase, generalization, topic selection and invention. In addition, improvements to the algorithm should also include the ability to diagnose the strategies used by students and give constructive feedback to enhance their summarizing skills.

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