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Submission date: 06-Apr-2023 12:11PM (UTC+0700)
Submission ID: 2057300717
File name: A_3a_A_Latent_Semantic_Analysis.pdf (856.61K)
Word count: 3341
Character count: 16456

Journal of Physics: Conference Series

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To cite this article: L Handayani *et al* 2020 *J. Phys.: Conf. Ser.* **1566** 012119

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A Latent Semantic Analysis Method for Automatic Scoring System at Essay Test

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Abstract. An essay test is the type of test that requires students' skills to propose, arrange, and combine the ideas they have from the teaching-learning process conducted. The essay answers in the form of description cause the examination becomes more complicated compared to an objective multiple-choice test. Therefore, in this research, the scoring system is built for an essay test by Using Latent Semantic Analysis that can pay attention to the word synonym of the key answer on the students' answer. The highest accuracy from the test that had been conducted at the essay scoring system by Using Latent Semantic Analysis was 84.35%, categorized into good.

1. Introduction

In teaching and learning activity, the test is an important part to evaluate the achievement and measure the level of students' comprehension in understanding the teaching material given by the teacher [1]. One of the general test forms given by the teacher is the essay. The essay answers in the form of description cause the checking becomes more complicated compared to an objective multiple-choice test because predominantly done conventionally by reading the answer of that essay one by one until it needs a long time in the process of checking. Almost 30% of the teacher's time spent to assess the result of students' tests [2]. Because the essay test is in the form of a description, a solution is necessary on how to check the answer of the essay test by using a method that can measure the similarity level of students' answers with the key answer provided.

Latent Semantic Analysis (LSA) is a method that represents the word into a matrix of semantics which then processed mathematically by using linear algebra technique which is Singular Value Decomposition (SVD) which compresses information related to big number into smaller space however it represents the real meaning [3]. Some research that has been done was The Implementation of Weighting Schemes at Automatic Essay Assessment Application Method Latent Semantic Analysis, the developed application can give correlation between manual assessment and system assessment in the amount of 39%, the correlation given was still low, this occurred because there was no system that considered the synonym between students' answer and the key answer [4]. At the research about Automatic Essay Grading System by Using Latent Semantic Analysis Method, the developed application could give assessment towards essay tests, however, the correlation between manual and system assessment was only 43.03% until 50.55%. This was also because there was no system that considered the synonym between students' answers and the key answers [5].

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In this research, assessment towards the essay test will be conducted using the Latent Semantic Analysis method by considering the synonym which is expected to able to improve the correlation between manual assessment and assessment given by the system.

This paper is structured as follows the second section is the theory of LSA, SVD, and similarity. The third section is the results and discussion in the analysis. The final section is a conclusion.

2. Latent Semantic Analysis

2.1. Latent Semantic Analysis

Latent Semantic Analysis (LSA) is a method that represents the words into a certain matrix of semantics which then processed mathematically by using linear algebra technique Singular Value Decomposition (SVD) which compresses information related in big number into smaller space however it represents the real meaning [3]. In conducting LSA, a matrix must be made from the arrangement of keywords from the document, the process of creating this matrix through text pre-processing, indexing, and weighting stages. The result of those three processes will form a matrix of words arrangement from the document, in LSA method it is defined as matrix A. Because not each keyword will emerge at each document, then matrix A is generally sparse, that is a condition in which there is much more element with 0 scores (Haley, et. al., 2005). Matrix A at LSA is defined as follows:

$$A = [a_{ij}] \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1j} \\ a_{21} & a_{22} & \dots & a_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ a_{i1} & a_{i2} & \dots & a_{ij} \end{bmatrix}$$

$$= A_{\bullet 1} \quad A_{\bullet 2} \quad \dots \quad A_{\bullet j} = \begin{bmatrix} A_{1\bullet} \\ A_{2\bullet} \\ \vdots \\ A_{i\bullet} \end{bmatrix} \tag{1}$$

In which *aij* is the presence frequency of keyword *i* at document *j* or generally called frequency term, *A•j* is column matrix that its element describes the emergence of each word in document to *j*. *Ai•* describing the emergent frequency of keyword *i* at each document.

2.2. Singular Value Decomposition (SVD)

After matrix A is formed, SVD process is done by using linear algebra technique by decomposing matrix A to be three singular matrices, they are Matrix U, matrix *Σ,* and matrix *Vt.* These matrices reflect the original relationship between document and keywords becomes linear-based vectors. Those matrices are defined as follows:

$$A = \begin{bmatrix} a_{1,1} & \cdots & a_{1,n} \\ \vdots & \ddots & \vdots \\ a_{m,1} & \cdots & a_{m,n} \end{bmatrix}$$

$$\begin{matrix} \quad U \qquad\qquad \Sigma \qquad\qquad V^T \end{matrix}$$

$$= \begin{bmatrix} \begin{bmatrix} u_1 \end{bmatrix} \dots \begin{bmatrix} u_r \end{bmatrix} \end{bmatrix} \cdot \begin{bmatrix} \sigma_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sigma_r \end{bmatrix} \cdot \begin{bmatrix} [& v_1 &] \\ & \vdots & \\ [& v_r &] \end{bmatrix}$$

(2)

In which *A* is the matrix with dimension *m x n,* and matrix *U* as the component of matrix *A* with dimension *m x n,* matrix *Σ* with *n x n* dimension, and matrix *VT* with dimension *n x n* [3]. The matrices of decomposition result from matrix *A* will be conducted decreasing on the dimension or called truncated SVD. In conducting truncated SVD, the score of *k* is determined first, in which the score of *k* does not exceed the wide the matrix results of decomposition. At the process of this dimension decreasing, SVD is viewed as a technique that is used to decrease the collection of index variables, in which each keyword

in the document can be represented as a vector in k space [3]. Figure 1 below shows the matrices of decomposition results from matrix A which had been conducted truncated SVD to it.

Figure 1. Matrix the Result of Truncated SVD from Matrix A

In LSA, truncated SVD operation produces matrix A_k which is not the same with the original matrix A. Matrix A_k is only an approach or approximation A at factor k. The keywords obtained in the same document will be close to each other in space k although those keywords never come together anymore in the same document. This means some documents that do not have any same keyword obtained in the query then it will not get close to query in space k [7].

2.3. Similarity

The core of LSA process is creating three singular matrices from matrix A which is created through text pre-processing stage that represents document terms into a matrix, after the matrix the result of SVD created, the query that its similarity score will be compared with the documents can be represented as vector in space k [4]. This vector will be compared with the document vector. Same as documents, before query vector is created, the pre-processing stage is also conducted to query first, after that then query vector in space k can be built with definition as follows:

$$\bar{\mathrm{q}} = q^T U_k \sum_{k=0}^{-1} \quad (3)$$

Where

$\bar{q}$: Query vector
q^T : Matrix transpose query vector
U_k : Left singular matrix in space k
Σ_k^{-1} : Singular matrix inverse in space k

To count query similarity with the document, likewise the query, each document is also needed to be built vector from the result of SVD decomposition defined as follows:

$$\bar{d} = d^T U_k \sum_{k=k}^{-1} \quad (4)$$

Where

$\bar{d}$: Document vector
d^T : Matrix transpose document vector
U_k : Left Singular Matrix in space k
Σ_k^{-1} : Singular matrix inverse in space k

After document vector and query vector formed then the similarity between query and document is calculated by counting the value of cosine angle created by query vector and document vector (Aji, et. al., 2011). The similarity of query vector and document query is defined as follows:

$$\cos \propto = \frac{\bar{q} \,.\, \bar{d}}{||\bar{q}||\,||\bar{d}||} = \frac{\sum_{i=1}^{n} \bar{q}_i x \bar{d}_i}{\sqrt{\sum_{i=1}^{n} (\bar{q}_i)^2}\, x \sqrt{\sum_{i=1}^{n} (\bar{d}_i)^2}} \quad (5)$$

Where

$\bar{q}$: Query vector
$\bar{d}$: Document vector
$\bar{q} \,.\, \bar{d}$: Product dot between query vector and document
$\|\bar{q}\|$: The length of query vector
$\|\bar{d}\|$: The length of document vector
$\|\bar{q}\|\|\bar{d}\|$: Product cross between $\|\bar{q}\|$ and $\|\bar{d}\|$

3. Result and Analysis

3.1. Analysis and Designing

For processing with LSA method consists of two stages, they are matrix decomposition and similarity measurement. For more obvious, Figure 2 describes the whole working system.

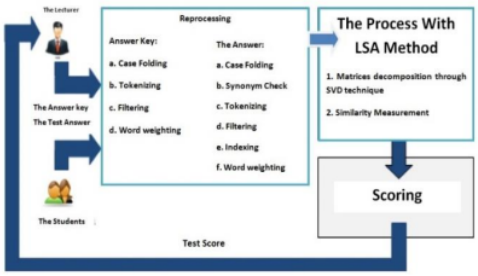

Figure 2. General Description of the System.

Pre-processing at this essay scoring system consists of two parts, they are pre-processing for query (the answer keys) and pre-processing for the collection of documents (students' answer), for more obvious, Figure 3 explains the stages conducted in pre-processing of the answer keys.

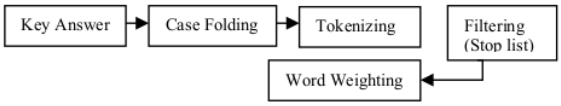

Figure 3. The Stages of Pre-processing Query (Key Answers).

As shown at Figure 3 the pre-processing of key answers only consists of case folding stage (change all words at the sentence to be all lowercase), tokenizing stage (break the sentence to be pieces of words), words weighting, and filtering (eliminate the unimportant words at the sentences), different from pre-processing which was conducted at students' answer like shown at the following figure 4.

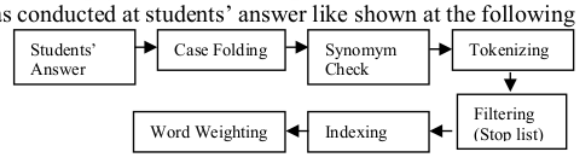

Figure 4. The Stages of Document Pre-Processing (Students' Answer).

Figure 4 explains pre-processing of students' answer obtained difference from pre-processing of the key answers which are the pre-processing of students' answer there was synonym check stage, indexing I (making word index from the sentences of students' answer), words weighting (giving the weight of the words based on indexing results). At the pre-processing of the key answers obtained synonym check stage, words checking of students' answers are conducted at this stage that has the same meaning with the words obtained in the key answers. For more details about the way of synonym check at this analysis will be explained in the flowchart shown in figure 5.

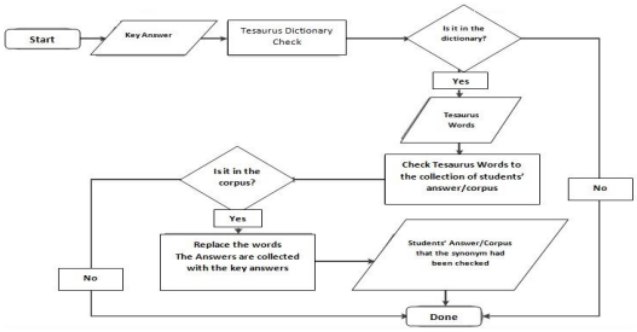

Figure 5. Flowchart of Synonym Check Process at Students' Answer.

The process of synonym check as shown by the flowchart at Figure 5, in the beginning, each word at the answer keys are checked at Thesaurus dictionary if the words at the key answers are not obtained in Thesaurus dictionary then the synonym check process is done, and if the words at the answer keys obtained in Thesaurus dictionary then the word synonym of the answer keys will be checked into the answers' collection, if the word synonym at the answer keys exist at answers collection then the words that become the synonym at students' answer collection are replaced with the words at the answer keys.

The Process of Essay Test Assessment through Latent Semantic Analysis Method

Based on the results of answer keys and students' answers pre-processing obtained beforehand, then in this part will be explained how is the usage of Latent Semantic Analysis Method in conducting assessment towards students' essay test answers. The following Figure 6 is the vector forming process flowchart of students' test answers. The vector forming process flowchart of the answer keys is shown by the following Figure 7. The scoring process flowchart of students' essay test answers is shown in Figure 8 below.

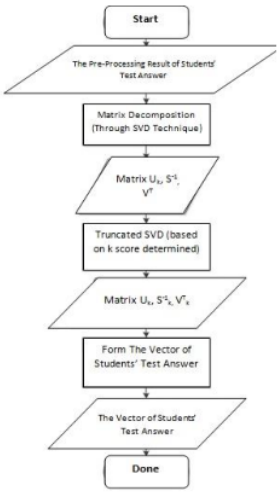

Figure 6. Vector Forming Process Flowchart of Students' Test Answer

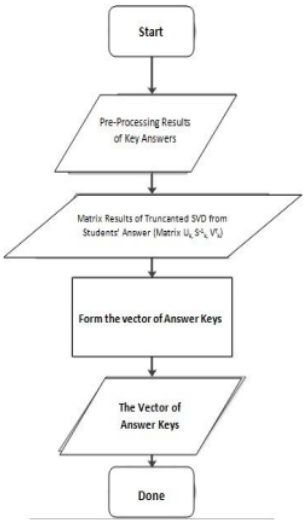

Figure 7. Forming Process Flowchart of Answer Keys Vector

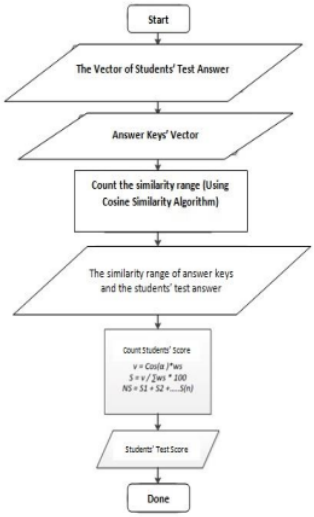

Figure 8. Scoring Process Flowchart of Students' Essay Test Answer

3.2. Implementation and Testing

1). The Limitations of Implication

The limitations of implementation at this analysis sentiment application are as follows:

a. Using programming language PHP, DBMS MySQL, and library matrix, Java Matrix (JAMA).

b. The numbers of essay questions are 5 items, and the students who answer are 34 students.

2). Testing Stages

The testing that will be done in the Essay Scoring System that has been built is as follows:

A) Testing to know if the system has run in accordance with the analysis and the design has been made done through the BlackBox testing method.

B) Accuracy testing of the essay test scoring system by using LSA (Latent Semantic Analysis) method done by counting the accuracy value given by the system towards the score given manually.

The first testing was done by using essay test data of the students at State Senior High School 4 Pekanbaru at PPKN (Civic Education) subject, with total 5 questions and total 34 students with each student had 5 test answers. The length of the essay answer at this test consists of one to three sentences. This test was conducted based on the scenario as follows:

a. The testing was done by using word weighting tf (term frequency) by doing the checking towards the synonym of the word of the answer keys and students' answers. The result is shown in table 1.
b. The testing was done by using words weighting tf (term frequency) without doing checking the words' synonym of the answer keys and students' answers. The result is shown in table 2.
c. The testing was done by using words weighting tf-idf (term frequency-inverse document frequency) by doing the checking towards the synonym of the word of the answer keys and students' answer. The result is shown by table 3.
d. The testing was done by using words weighting tf-idf (term frequency-inverse document frequency) without doing the checking towards the words synonym of the answer keys and students' answer. The result is shown by table 4.
e. At each scenario, k value given was k =2, k =5, k = 8, k=11, and k = 14.

The second testing was done by using essay test data of undergraduate students of State Islamic University of Sultan Syarif Kasim Riau Informatics Engineering Major at Design and Algorithm Analysis Course, with total 3 questions and 32 students with each student had 3 test answers. The length of the answer of the essay test is more than 3 sentences. The result is shown by table 5.

C) The testing was done towards the essay test answers containing polysemy words. The result is shown by table 6.

Table 1. Result Testing Using tf and Checking Synonym

No	*Name*	*MS*	SS_{K2}	SS_{K5}	SS_{K8}	SS_{K11}	SS_{K14}
1	Adi	73	96	74	59	53	52
2	Ahmad R	80	90	67	56	49	49
3	Ahmad N	60	95	71	56	47	45
…	…	…	…	…	…	…	..
34	Yuni	40	45	22	13	11	10
	Accuracy		74.78 %	73.81 %	64.53 %	56.94 %	50.22 %

Table 2. Result Testing Using tf and Without Checking Synonym

No	*Name*	*MS*	SS_{K2}	SS_{K5}	SS_{K8}	SS_{K11}	SS_{K14}
1	Adi	73	94	77	58	49	46
2	Ahmad R	80	89	63	50	44	41
3	Ahmad N	60	86	58	45	40	34
…	…	…	…	…	…	…	..
34	Yuni	40	47	23	13	12	11
	Accuracy		78.15 %	73.12 %	61.97 %	51.96 %	46.20 %

Table 3. Result Testing Using tf-idf and Checking Synonym

No	*Name*	*MS*	SS_{K2}	SS_{K5}	SS_{K8}	SS_{K11}	SS_{K14}
1	Adi	73	88	79	65	49	38
2	Ahmad R	80	87	55	51	38	30
3	Ahmad N	60	88	79	65	34	32
…	…	…	…	…	…	…	..
34	Yuni	40	56	15	13	6	5
	Accuracy		71.48 %	68.32 %	62.34 %	49.81 %	37.29 %

Table 4. Result Testing Using tf-idf and Without Checking Synonym

No	*Name*	*MS*	SS_{K2}	SS_{K5}	SS_{K8}	SS_{K11}	SS_{K14}
1	Adi	73	88	75	54	42	37
2	Ahmad R	80	89	50	44	31	27
3	Ahmad N	60	86	69	66	29	24
…	…	…	…	…	…	…	..
34	Yuni	40	71	25	23	15	14
	Accuracy		68.00 %	67.64 %	56.39 %	44.24 %	34.14 %

Table 5. Result Testing of Student with 3 answers

No	*Name*	*MS*	*SS*	*Deviation*
1	Arif	75	83	8
2	Akmal	75	97	22
3	Aldilah	80	69	11
…	…	…	…	..
34	Yulia	75	90	15
	Accuracy			84.35%

Table 6. Result Testing of Student with 3 answers

No	*Pengujian*	*MS*	*SS*	*Deviation*
1	"Bisa"	0	100	100
2	"Bunga"	0	100	100
3	"Buah"	0	100	100
4	"Raja"	0	100	100
5	*"Kepala"*	0	100	100
	Accuracy			0 %

4. Conclusion

Based on the research that has been conducted then it can be concluded that:

1. LSA (Latent Semantic Analysis) Method can be applied to design the scoring system at an essay test with the highest accuracy level in this research was 84.35%.
2. The essay test scoring system that has been built can do essay test scoring by considering the synonym of the word of the answer keys and students' answers.
3. The scoring by considering the synonym of the answer keys and students' answers is proven to be able to improve the accuracy of essay test scoring from the scoring without considering the synonym.
4. The system of essay test scoring at this research still cannot consider the polysemy words obtained at essay test answers. This is because conducting the checking towards the answer that contains polysemy must know the sentence structure from the essay answers, while at the system that has been built still cannot do that.
5. The performance of the scoring given by essay test scoring system by using LSA (Latent Semantic Analysis) Method is influenced by some factors; they are:
   a. The words used by the students in answering the essay,
   b. Determining the best *k* score,
   c. Weighting the words used at the pre-processing stage,
   d. The length of the essay test answer

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