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# Automatic Assessing System of Operating Process based on Needleman-Wunsch Algorithm

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## Abstract

**By studying the characteristics of certain practical questions, this paper proposes an operating process assessing system based on the Needleman-Wunsch algorithm, aiming to address the general lack of universality, insufficient emphasis on assessing the operating process, and excessive subjectivity in the current practical assessing methods. This system converts operating steps into operation sequences. It utilizes the Needleman-Wunsch algorithm to compare the standard operation sequences with the actual operation sequence, thus assessing the operating process. The results indicate that this system applies to operation questions, meets manual scoring requirements, and can objectively reflect students' operation abilities.**

## Keywords

**Operating Process; Automatic Assessing Method; Sequences Alignment; Needleman-Wunsch Algorithm.**

## 1. Introduction

Assessing students' operating processes has always been a focus and difficult question in virtual practical teaching. Currently, the scoring methods of practical assessing systems mainly include the deduction-based method [1], (multi-level) fuzzy comprehensive evaluation method [2][3], cloud gravity judgment method [4], etc. With the development of virtual practice, the deduction-based method no longer applies to complex problems. On the other hand, methods such as fuzzy evaluation are complex to implement, subjective, and struggle to adapt to the changing operating processes; focusing solely on results is unfair [5]. Therefore, proposing a universal and objective method for assessing practical processes is meaningful.

In this paper, we propose an operating process assessing system: Formost operation questions, one or more standard sequences can be used to represent them, and after the student completes the operation, the data collection device can be used to collect the student's operation sequence. Therefore, by using the double sequence alignment algorithm to compare the student operation sequence with the standard operation sequence, their similarity can be obtained, thereby determining the student's operation situation.

## 2. Automatic Assessing Method

The double sequence comparison algorithm, which utilizes the dynamic programming approach, can obtain the optimal alignment results of two sequences to be compared. It is commonly used in bioinformatics for gene sequence alignment problems. Some scholars have recently applied this algorithm in user trajectory recognition algorithms [6] and user recommendation algorithms [7]. The most well-known double sequence comparison algorithms are the Needleman-Wunsch and Smith-Waterman algorithms [8]. Among them, the Needleman-Wunsch algorithm is more suitable for

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assessment processes requiring the determination of matched elements and sequence lengths. Therefore, selecting the Needleman-Wunsch algorithm is more appropriate.

## 2.1 Needleman-Wunsch Algorithm

The Needleman-Wunsch algorithm is a global sequence alignment algorithm. Its basic principle involves scoring the alignment of elements from two different sequences using dynamic programming. This process forms a score matrix, which is then traced back using backtracking techniques to obtain an optimal path, representing the best alignment result [9]. The implementation of this algorithm involves four steps in total:

Assume that the sequence of operations operated by a student is T, and the standard sequence of operations is S. The details of the two sequences are shown in Table 1.

**Table 1.** Student's operation sequence and standard operation sequence

| Name | Content |
|---|---|
| S | 1 →2 →3 →4 →5 |
| T | 1 →2 →4 →3 →5 |

(1) Penalty score rules

When calculating the score matrix, it is necessary to set the corresponding penalty score rules. The formula is shown below:

$$\sigma(S_i,T_j)=\begin{cases} \text{match}, & S_i=T_j \\ \text{mismatch}, & S_i\neq T_j \\ \text{indel}, & S_i='-' \text{ or } T_j='-' \end{cases} \quad (1)$$

Where "match" means the score of two elements matching; "mismatch" means the score of two elements not matching; "indel" means the score of misaligning; $S_i$ means the i-th element of sequence S; $T_j$ means the j-th element of sequence T. In this instance, we set the match = +2, the mismatch = -2, and the indel = -1.

(2) Filling the score matrix

Filling the score matrix is the iterative computation of $M_{i,j}$. According to the concept of dynamic programming, the value of $M_{i,j}$ is determined by $M_{i-1,j}$, $M_{i,j-1}$ and $M_{i-1,j-1}$. The iterative formula is as follows.

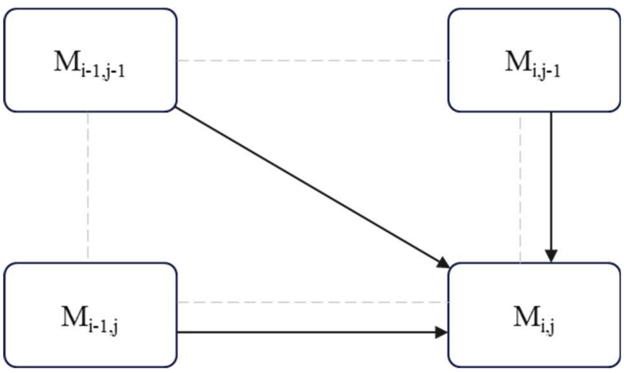


**Figure 1.** Partial contents in the score matrix

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$$M_{i,j} = \max \begin{cases} M_{i-1,j-1} + \sigma(S_i, T_j) \\ M_{i-1,j} + \sigma('-', T_j) \\ M_{i,j-1} + \sigma(S_i, '-') \end{cases} \quad (2)$$

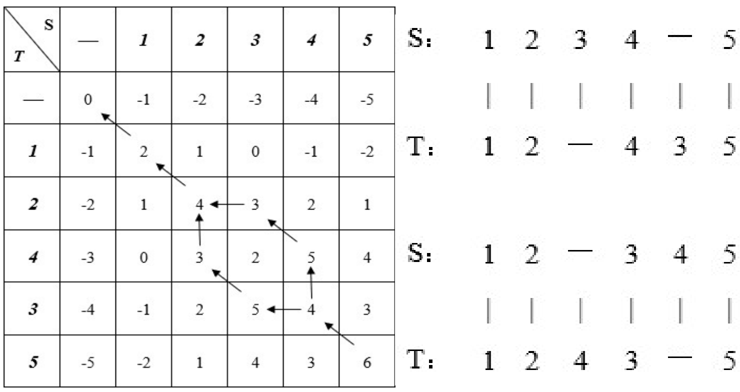
The score matrix shown in Figure 2 can be obtained based on the iterative formula (2).

| T \ S | — | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| — | 0 | -1 | -2 | -3 | -4 | -5 |
| 1 | -1 | 2 | 1 | 0 | -1 | -2 |
| 2 | -2 | 1 | 4 | 3 | 2 | 1 |
| 4 | -3 | 0 | 3 | 2 | 5 | 4 |
| 3 | -4 | -1 | 2 | 5 | 4 | 3 |
| 5 | -5 | -2 | 1 | 4 | 3 | 6 |

**Figure 2.** Score matrix

(3) Backtracking the optimal path

When all values in the scoring matrix are computed, the optimal global alignment result of the sequences can be obtained by starting from the bottom-right corner of the scoring matrix and backtracking according to the calculation directions used in generating the scoring matrix until reaching the top-left corner. The backtracking paths and the alignment results, as shown in Figure 3, can be derived accordingly.




(a) backtracking paths (b) Alignment results

**Figure 3.** Backtracking results

(4) Calculation of the similarity

The similarity of two sequences is calculated based on the similarity between the number of matching elements and the sequence length after backtracking.

$$S = n / m. \quad (3)$$

Among them, n is the number of matching elements, and m is the length of the backtracked sequence.

## 2.2 Algorithm Optimization

Due to the extensive calculations and comparisons required by the Needleman-Wunsch algorithm, especially when dealing with large datasets, it can be computationally expensive [10]. However, since the length of the operation sequences is relatively short, the impact is negligible compared to DNA sequence lengths. Therefore, this paper primarily focuses on improving and supplementing the backtracking process and scoring calculation process.

(1) Backtracking process

Figure 3(b) shows that the branches in the backtracking process may produce multiple sets of alignment results, and our goal is to obtain the optimal alignment result. Therefore, the following improvements have been made to the backtracking technology:

If $S_i = T_j$, the backtrack to the top-left corner cell;

If $S_i \neq T_j$, the backtrack to the maximum value of top-left corner cell, top cell, and left cell. When multiple maximum values exist, priority is backtracked in the order of top-left corner cell, top cell, and left cell.

(2) The calculation process of scoring

As the operation questions become increasingly complex, the standard operation for most questions is no longer just an ordered sequence, and there may be multiple standard sequences. Therefore, we need to compare the student's operation sequence with the standard sequence one by one and use the optimal result as the student's operating score A.

$$A = \max(S1, S2, \cdots SZ). \quad (4)$$

Among them, z is the number of standard sequences.

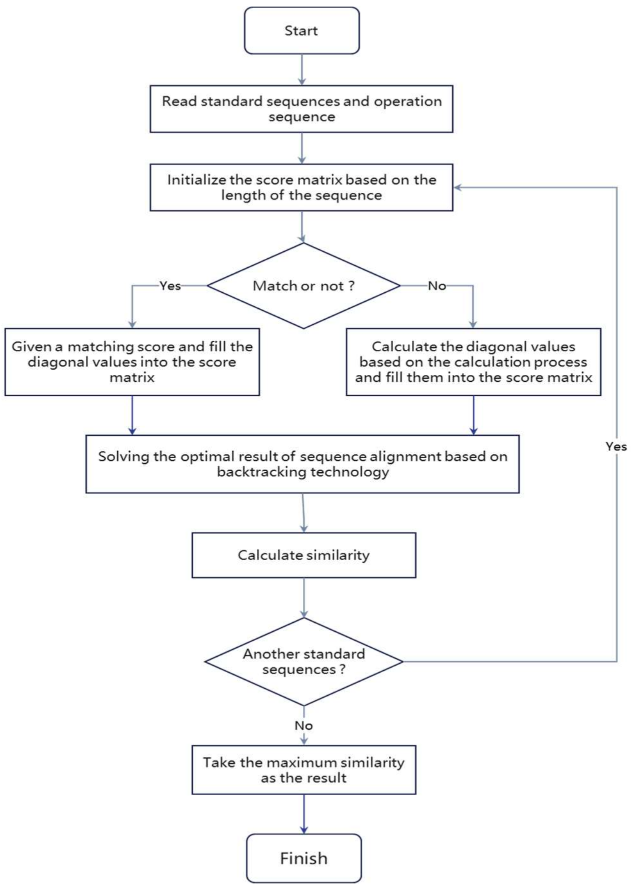



**Figure 4.** Flow chart of improved automatic assessing method

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# 3. Automatic Assessing System Design and Instance

The system requires students to select appropriate questions for operation on the front-end interface. During the student's operating process, the data collection module collects data from the training equipment to obtain information about the student's operating process and parses it into an operation sequence. After the student completes the operation, the automatic assessing module utilizes a double sequence comparison algorithm to compare the collected operation sequence with the standard sequence. It selects the maximum value as the student's operating score. Simultaneously, the database stores the relevant important information throughout the entire process.

## 3.1 Automatic Assessing System

Based on the above requirements. The structure of the system is shown in Figure 5. The composition of the automatic evaluation system includes: training equipment, front-end interface, data collection module, automatic scoring module, data reading and writing module, and database.

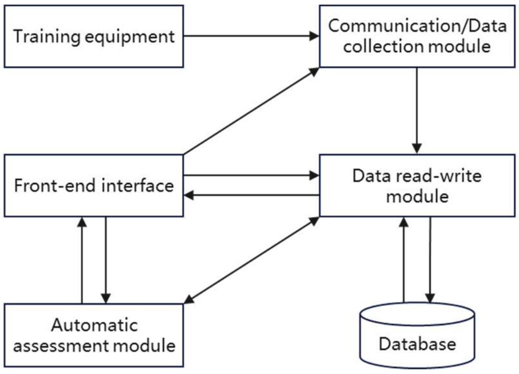


**Figure 5.** The structure of the automatic assessing system

## 3.2 Instance

Assuming that in a specific assessment, there is a question called " Manual synchronization and paralleling of generators" [11], which requires students to operate in manual mode, start the generator to integrate it into the power grid, and transfer and distribute loads.

**Table 2.** The requirements of " Manual synchronization and paralleling of generators"

| Steps No | Steps Name |
|---|---|
| a1/a2/a3 | Set 3 generators to manual position |
| b | Start generator 2 |
| c | Check the voltage and frequency of generator 2 |
| d | Turn on the synchronization dial |
| e | Regulate the frequency |
| f | Close generator 2 |
| g | Turn off the synchronization dial |
| h | Perform power distribution adjustment for generators 1 and 2 |

The first step is to read the standard and the student's operation sequences. The standard sequences according to the question are shown in Table 3. We select two students, A and B, with different levels of operation, to complete the operations of the question. At the end of operations, the operation result

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returned by student A is: a1 →a2 →a3 →b →c →d →e →f →h. The operation result returned by student B is: b →a1 →a3 →a2 →b →f →d →e →f →h.

**Table 3.** The standard sequences of " Manual synchronization and paralleling of generators"

| Sequence No | Sequence Content |
|---|---|
| 1 | a1 →a2 →a3 →b →c →d →e →f →g →h |
| 2 | a1 →a3 →a2 →b →c →d →e →f →g →h |
| 3 | a2 →a1 →a3 →b →c →d →e →f →g →h |
| 4 | a2 →a3 →a1 →b →c →d →e →f →g →h |
| 5 | a3 →a2 →a1 →b →c →d →e →f →g →h |
| 6 | a3 →a1 →a2 →b →c →d →e →f →g →h |

The second step is to set penalty score rules. According to formula (1), the penalty point rule is shown below.

$$\sigma(S_i,T_j)=\begin{cases} 2, S_i=T_j \\ -2, S_i\neq T_j \\ -1, S_i='-' \text{ or } T_j='-' \end{cases} \quad (5)$$

The third step is to calculate the score matrix. According to the formula (5) and iterative formula (2), calculate the score matrix:

| T \ S | — | a1 | a2 | a3 | b | c | d | e | f | g | h |
|---|---|---|---|---|---|---|---|---|---|---|---|
| — | 0 | -1 | -2 | -3 | -4 | -5 | -6 | -7 | -8 | -9 | -10 |
| a1 | -1 | 2 | 1 | 0 | -1 | -2 | -3 | -4 | -5 | -6 | -7 |
| a2 | -2 | 1 | 4 | 3 | 2 | 1 | 0 | -1 | -2 | -3 | -4 |
| a3 | -3 | 0 | 3 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | -1 |
| b | -4 | -1 | 2 | 5 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| c | -5 | -2 | 1 | 4 | 7 | 10 | 9 | 8 | 7 | 6 | 5 |
| d | -6 | -3 | 0 | 3 | 6 | 9 | 12 | 11 | 10 | 9 | 8 |
| e | -7 | -4 | -1 | 2 | 5 | 8 | 11 | 14 | 13 | 12 | 11 |
| f | -8 | -5 | -2 | 1 | 4 | 7 | 10 | 13 | 16 ← | 15 | 14 |
| h | -9 | -6 | -3 | 0 | 3 | 6 | 9 | 12 | 11 | 10 | 17 |

**Figure 6.** Score matrix and backtracking path (one of all situations)

The fourth step is backtracking. According to the modified backtracking technique, the score matrices were backtracked to obtain one of the backtracking paths shown in Figure 6 and one of the alignment results shown in Figure 7.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| S: | a1 | a2 | a3 | b | c | d | e | f | g | h |
| | \| | \| | \| | \| | \| | \| | \| | \| | \| | \| |
| T: | a1 | a2 | a3 | b | c | d | e | f | — | h |

**Figure 7.** Alignment result (one of all situations)

The fifth step is to calculate the score. According to the formulas (3) and (4), student A gets 90 points, and student B gets 73 points. From the results and grades of the students, it can be seen that the level of student A is higher than student B. Through analysis, it can be found that the scores given by the automatic scoring method are reasonable.

## 4. Conclusion

The system transforms the operational content of the questions into one or multiple standard sequences. It collects and converts students' operations into operation sequences using data acquisition devices. The Needleman-Wunsch algorithm compares the standard sequences with the operation sequences to obtain their similarity. Ultimately, it provides the optimal student performance score after completing the operations. In addition to its simplicity and universality, this scoring method provides the operator's performance score through the computer, significantly eliminating subjective factors and ensuring objective and fair results. The paperless examination and automatic scoring of practical assessments using computer implementation have significant practical application significance and promotional value.

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