Fingerprint Identification using Bozorth and Boyer-Moore Algorithm

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Abstract. The process of fingerprint identification in the form of a binary image can be performed with a variety of algorithms to matching the fingerprint process. This study aims to determine the time processing for fingerprint detection using Bozorth and Boyer-Moore models. The result showed that both of the models could detection the fingerprint. This paper contribution is to compare and analyze Bozorth and Boyer-Moore algorithms. The comparison is performed by MATLAB simulation. The simulation results Boyer-Moore algorithm has faster identification process. On the other hand, Bozorth algorithm has an advantage for identification of effect rotated or space translated fingerprints.

1. Introduction
Technological developments led to the discovery that humans perform various sophisticated human identification. There are several methods used to perform human identification, one of the most popular method, is to use a password or a PIN (Personal Identification Number). Recently, biometric is endorsed to use for better access security. The fingerprint identification is one of biometric technology with utilizing the shape of a person's fingerprints that cannot be imitated by others. The algorithms that are observed to minutiae detection algorithm [1] and the string fingerprint algorithm [2], which are methods of fingerprint recognition algorithm using Bozorth and Boyer-Moore algorithm.

The previous research indicated that the image enhancement technique based on segmentation, oriented-field estimation and ridge frequency was filtered by wavelet transform [3]. The result of this study shows that the model can handle various input contexts. Ravi. J et al. [3] studied in fingerprint recognition employing minutiae score matching model namely Fingerprint Recognition using Minutia Score Matching method (FRMSM). The performance of this study shown better false matching ratios (FMR) compared with the Fingerprint Recognition Fuzzy Neural Network (FRFNN). The study in [4] proposed a gray level watershed method to identify the fingerprint and find out the ridges present on a fingerprint image by scanned the fingerprint directly.

This study aims to determine the time processing for fingerprint detection using Bozorth and Boyer-Moore models. The result showed that both of the models could detection the fingerprint. However, the Boyer-Moore model obtained a faster time than Bozorth model in the detection process.
2. Method of Study

In this section, we describe in the fingerprint identification algorithms work.

2.1. The Fingerprint: A Review

A fingerprint is the ridges and valley pattern which has unique fingerprints. The uniqueness of a fingerprint is exclusively determined by the local ridge characteristics and their relationships [5]. The minutiae are prominent local ridge characteristics. The minutiae consist of two-part such as the ridge ending and the ridge bifurcation. The ridge ending is defined as the point where a ridge ends abruptly. The ridge bifurcation is defined as the point where a ridge forks or diverges into branch ridges. A good quality fingerprint typically contains about 40-100 minutiae (Figure 1) [6] [7] [8].

![Figure 1. Minutiae: (a) ridge ending (square mark) (b) bifurcation (circle mark) [5, 6]](image)

2.2. Bozorth Algorithm

The BOZORTH3 matcher uses only the location \((x, y)\) and orientation \((\theta)\) of the minutiae points to match the fingerprints. The matcher builds separate tables for the fingerprints matched that define distance and orientation between minutiae in each fingerprint [9] [10].

Two key things are important to note regarding this fingerprint matcher [9]:

1. Minutiae features exclusively used and limited to location \((x, y)\) and orientation ‘\(t\)’ represented as \([x, y, t]\)
2. The algorithm is designed to be rotation and translation invariant

The algorithm comprised of three major steps [9]:

1. Construct Intra-Fingerprint Minutiae Comparison Tables: One Table for the probe fingerprint and one table for each gallery fingerprint to match against
2. Construct an Inter-Fingerprint Compatibility Table: Compare a probe print’s minutiae comparison table to a gallery print’s minutiae comparison table and construct a new compatibility table.
3. Traverse the Inter-Fingerprint Compatibility Table: Traverse and link table entries into a new table and combine compatible table and accumulate a match score.

2.3. Boyer-Moore Algorithm

The Boyer–Moore algorithm is an efficient string-searching algorithm that is the standard benchmark for practical string search literature [11], which was developed by Robert S. Boyer and J Strother Moore in 1977 [2] [12].

Systematically, the steps undertook Boyer - Moore algorithm when the match string is [6]:

1. Boyer - Moore algorithm started matching pattern at the beginning of the text.
2. From right to left, this algorithm will match a character-by-character pattern with the corresponding character in the text, until one of the following conditions met:
   a. The characters in the pattern and the text than not match (mismatch).
   b. If all the characters in pattern matching, then the algorithm will notify discovery in this position.
   c. The algorithm then shift pattern to maximize the value of the right - suffix shift and bad - character shift, then repeat steps 2 through pattern at the end of the text.
3. Result and Discussion

MATLAB Software performs implementation of Bozorth and Boyer-Moore algorithm to the identification of the fingerprint. Three patterns of the fingerprint used in this simulation, which is a regular pattern, pattern half erased and rotated pattern.

3.1. Implementation of Bozorth Algorithm

Figure 2 describes the fingerprint recognition process done by matching minutiae location data retrieved from the fingerprint image into an existing database. Minutiae location data is used to calculate the distance and angle of two adjacent minutiae in a fingerprint. If the value of the distance and angle in the fingerprint has calculated, it can be compared with the distance and angle of fingerprint minutiae on the other.

![Figure 2. The way of working of Bozorth algorithm](image)

3.2. Implementation of Boyer-Moore algorithm

Figure 3 described fingerprint recognition process done by matching the string data taken from an existing fingerprint image. The images used in the matching process for the two algorithms with a 240x320 pixel full fingerprint images captured by 30 pixels every time the data matching process. The 8-bit ASCII characters represent a Boyer-Moore matching process with the data strings. The process of matching data on the Boyer-Moore performed on each character; this causes the matching process becomes slow because of the variation of the character of one or zero. To overcome this grouping is done per line per 8-bit binary code to form the ASCII characters.

![Figure 3. The way of working of the Boyer-Moore algorithm](image)

The simulation result on MATLAB by testing the pattern for fingerprint identification shown in Figure 4. The same sample of a fingerprint is evaluated and identify by both Bozorth algorithm and the Boyer-Moore string search algorithm. The result of identification using Bozorth algorithm are some minutiae location, and identification using the Boyer-Moore algorithm result set of string data that converted from one fingerprint.
Boyer-Moore Algorithm Analysis

The example below is an example of a change of strings taken with dimensions 30x8 who made a string of rows. String before being converted to ASCII 8 bits (Figure 5):

![Figure 5. Data binary of fingerprint](image)

String after converted to ASCII 8 bits from Figure 5:

```
sb|MWejC
```

After a string of fingerprint data obtained, it can be done fingerprint matching process using string data per row of data using the Boyer-Moore algorithm.

Bozorth Algorithm Analysis (Table 1).

| X  | y  | t  |
|----|----|----|
| j₁ | 10 | 5  | 90 |
| j₂ | 15 | 10 | 180|
| k₁ | 25 | 20 | 45 |

Table 1 is a set of minutiae of one fingerprint. From the x, y, and t point, we can count distance and angle that used to compare two fingerprints using Bozorth algorithm. The examples below explained of counting process of that minutia of one fingerprint.
The formula to count distance denoted below.

\[ d_{x_i} = X_{ji} - X_{ki} \]  
\[ d_{y_i} = Y_{ji} - Y_{ki} \]  
\[ d_{kij} = d_{x_i}^2 + d_{y_i}^2 \]

\( i = \text{number of distances} \)

From the example, we can count minutiae \( x \) and minutiae \( y \) to get distance.
\( j_1 = 10, k_1 = 15, j_2 = 25, k_2 = 180, t_1 = 90, t_2 = 180, t_2 = 45 \)
\( d_{x1} = X_{j1} - X_{k1} = 10 - 15 = -5 \)
\( d_{y1} = Y_{j1} - Y_{k1} = 5 - 10 = -5 \)
\( d_{x2} = X_{j2} - X_{k2} = 10 - 20 = -10 \)
\( d_{y2} = X_{j2} - X_{k2} = 15 - 25 = -10 \)
\( d_{k1j1} = d_{x1}^2 + d_{y1}^2 = (-5)^2 + (-5)^2 = 50 \)
\( d_{k2j2} = d_{x2}^2 + d_{y2}^2 = (-10)^2 + (-10)^2 = 200 \)

The formula to count theta \( t \)
\[ \theta_{kji} = \tan \left( \frac{d_{yj}}{d_{xi}} \right) \]  
\[ \beta_{kji} = \theta_{kji} - t_{kji} \]  
\[ \beta_{ji} = \theta_{kji} - t_{ji} \]

From the example, we can count minutiae \( x \) and minutiae \( y \) to get \( \theta (\Theta) \).
\( \Theta_{kji} = \tan \left( \frac{d_{x1}/d_{x1}}{d_{x1}/d_{x1}} \right) = \tan \left( \frac{-5/-5}{} \right) = 0.017 \)
\( \beta_{kji} = \theta_{kji} - t_{kji} = 0.017 - 180 = 179.983 \approx 180 \)
\( \beta_{ji} = \theta_{ji} - t_{ji} = 0.017 - 90 = 89.983 \approx 90 \)
\( \Theta_{kji} = \tan \left( \frac{d_{x2}/d_{x2}}{d_{x2}/d_{x2}} \right) = \tan \left( \frac{-10/-10}{} \right) = 0.017 \)
\( \beta_{kji} = \theta_{kji} - t_{kji} = 0.017 - 45 = 44.983 \approx 45 \)
\( \beta_{ji} = \theta_{ji} - t_{ji} = 0.017 - 180 = 179.983 \approx 180 \)

From the result of the distance and angle of one fingerprint, we can compare the distance and angle from two fingerprints. If the relative distance and minutiae angles between the two comparison table entries are within an acceptable tolerance, then two fingerprints are matching and will display distance and angle from the fingerprint. The formula to get the match score of comparing two fingerprints is.

\[ \Delta_d \left( d(P_m), d(G_n) \right) = d(P_m) - d(G_n) < T_d \]  
\[ \Delta_{\beta} \left( \beta_1(P_m), \beta_1(G_n) \right) = \beta_1(P_m) - \beta_1(G_n) < T_{\beta} \]  
\[ \Delta_{\beta} \left( \beta_2(P_m), \beta_2(G_n) \right) = \beta_2(P_m) - \beta_2(G_n) < T_{\beta} \]

\( P_m \) is the first fingerprint called probe and \( G_n \) is the second fingerprint called gallery. If the distance and minutiae angles between the two comparison table entries are with acceptable tolerance, then two fingerprints are matching and will display distance and angle from the fingerprint.

Figure 6 described the three patterns that used for fingerprint identification process is a regular pattern, a pattern that partially erased, and the pattern rotated. The square-shaped red mark is an area matching fingerprints taken.

Processing time to detection the fingerprint using both algorithms denoted as below.
\[ T_P = \frac{T_m}{n} \]  

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\( T_p \) = Processing time to matching fingerprint
\( T_m \) = time of all minutiae or string fingerprint that match
\( n \) = number of minutiae or string of fingerprint

From the test results shows that the Bozorth algorithm can recognize fingerprints for all pattern either standard pattern, pattern half erased or rotated pattern while the Boyer-Moore string search algorithm can only recognize the standard pattern and the pattern half erased. For a pattern that can be rotated still not well recognized by the Boyer-Moore algorithm. The processing time of fingerprint identification, the Boyer-Moore algorithm is faster than the Bozorth algorithm. The Bozorth and the Boyer-Moore algorithms obtained a faster time compared with (Figure 6) [5] [3].

| Fingerprint | Identification Fingerprint | Processing Time |
|-------------|----------------------------|-----------------|
| ![Fingerprint] | ![Matching Fingerprint] | ![Processing Time] |

**Figure 6.** Fingerprints with that representation and processing time to identify patterns of two fingerprints using Bozorth and Boyer-Moore algorithm

**4. Conclusion**

This paper compares the fingerprint identification using Bozorth algorithm and Boyer–Moore algorithm. From the results of the testing that has been done, it is seen that the Bozorth algorithm can recognize fingerprints on a standard pattern fingerprint, pattern half erased or rotated pattern. In the Boyer-Moore algorithm, the fingerprint can only be recognized by both the standard pattern fingerprint and pattern half erased, while the fingerprint pattern that is rotated, the algorithm is still experiencing difficulties in
reading the fingerprint pattern string. Time processing of fingerprint identification, the Boyer-Moore algorithm is faster than the Bozorth algorithm.

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