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Short Paper

Single Switch Chinese Phonetic Communication System

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Morse code, with its single switch operation, has been shown to be an excellent adaptive communication device for the disabled, especially those with impaired hand coordination and dexterity. Because a stable typing rate is required for an accurate recognition of Morse code, it presents a major hindrance to disabled persons in applying Morse code as a useful communication tool. Therefore, a suitable adaptive recognition method is needed. This paper applies the Least-Mean- Square algorithm to an adaptive Chinese phonetic Morse code recognition system which includes four processes: space recognition, tone recognition, adaptive processing, and character recognition. Statistical analyses demonstrated that the proposed method results in a better recognition rate compared to alternative methods in the literature.

Keywords: Morse code, adaptive signal processing, least-mean-square algorithm, Friedman test, multiple comparison test

1. INTRODUCTION

Computer use, accompanied by the rapid growth of information technology, is emerging as a major trend. Most products manufactured now, however, are designed for disabled persons and, thus, are often inaccessible to the disabled. In fact, for disabled persons, technology alone has not yet helped improve their daily lives. Disabled persons often need auxiliary tools to use technological devices originally designed for

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disabled persons. As technology advances, these adaptive tools will increasingly play a more important role in their lives. Of all the adaptive devices, the ones to assist with computer input are the most important. Unaltered input devices for computers, such as the mouse and keyboard, are designed for disabled persons, denying physically disabled persons useful communication methods. Nonetheless, the disabled do require methods of entering text into a computer for purposes of augmentative and alternative communication in their daily lives. Thus, many attempts have been made to develop computer-assisted key-in systems for the disabled, such as head mouse, mini-keyboard, king-keyboard, trackball, joystick, alternative keyboard, keyguard, and touch screen.

In addressing this task many researchers have focused on a reduced set of switches with an efficiency approaching one key press per selected character. To aid those persons whose hand coordination and dexterity are impaired by such ailments as muscle atrophy, cerebral palsy, and other severe handicaps, a substitute keyboard is necessary. The most often applied device is Morse code using an easily-operated, single switch which has been shown to be an excellent adaptive communication device [1-6]. Morse code is a most basic means of transmitting signals by a tone-silent time series, dot and dash being defined as unequal tone intervals which are generated by a switch down condition.

According to result of the computer skills test conducted by the Chinese Computer Foundation of the Republic of China over the past three years, the Chinese phonetic input method used in the R.O.C. has been one of the most popular methods of input. Therefore, we edited the Chinese phonetic Morse code to allow disabled persons to use Chinese version computer applications [7]. However, a severely physically disabled person usually generates an unstable Morse code time series. Therefore, a suitable adaptive recognition method is required to recognize the unstable Morse code time intervals produced. In this paper, the Least-Mean-Square (LMS) algorithm [8] and a new adjustment method were used for adaptive processing on the problem of Chinese phonetic Morse code recognition for the disabled. Experimental results revealed that the proposed method provides a superior recognition rate when compared to previous results in the literature [3, 9].

2. METHOD

The tone ratio of Morse code (dot to dash) is defined as 1:3 and the ratio of silent dot-space to character-space is the same. So, if a dot has unit length, then a dash has three units. Automatic recognition of Morse code is such a challenge because it is difficult for the disabled to maintain a stable typing rate. [2, 3]. In 1996, Luo and Shih [2] used an adaptive technique, the Least-Mean-Square (LMS), to recognize varying typing speeds. However, their proposed system was limited to detecting variation, performing well only within a range of two-thirds to two times the normal typing rate. As a result, their method could not be effectively used by most beginners or by people with very serious disabilities. Subsequently, Shih and Luo [3] proposed an improved method that combined the Least-Mean-Square algorithm with a character-by-character matching technique to overcome this limitation. More recently, Yang [9] has proposed a statistical method to solve this performance problem, and which provides encouraging results.

In this paper we address the same issues, yet attempt to develop a more efficient and effective method. The method we are proposing can be divided into the following processes: space recognition, tone recognition, adaptive processing, and character recognition. To begin the process, whether the input data stream proceeds first to space recognition or tone recognition depends upon whether the value of the input element arises from a key release event (space element) or key pressed down event (tone element). If the detected element is a space element, the first step is to determine whether it is a space between dot-dash or a space between characters. If the space element is detected as a character space, then the value(s) in the tone buffer is sent to the character recognition process. If detected as a character space, the element value is divided by a constant (3.0) before being fed into the adaptive processing stage. Otherwise, the space element value is fed directly into the adaptive stage. Conversely, if the detected element is a tone element, the element is first determined to be either a dot or dash before being sent to tone-base adjustment. Simultaneously, in the tone buffer section, the recognized tone element (dot or dash) and each subsequent tone element are stored separately in a dot-dash buffer and tone element buffer. Once the tone element value is sent to tone base adjustment, the character can be recognized in character recognition.

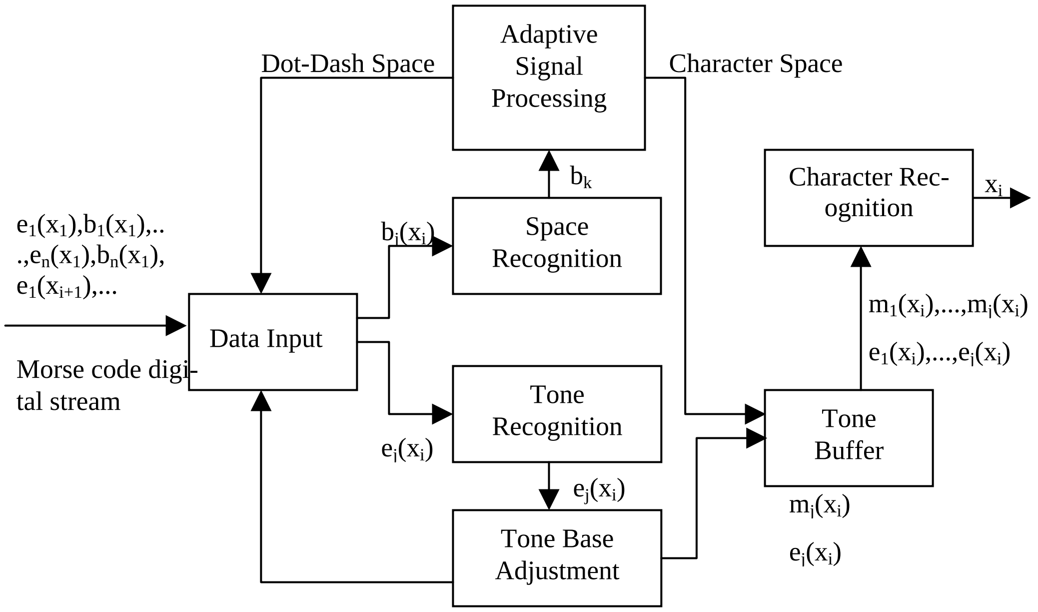

Fig. 1. Block diagram of the Chinese phonetic Morse code recognition system.

A Morse code character, x_i, is represented as follows:

$e_1(x_i)$, $b_1(x_i)$, …, $e_j(x_i)$, $b_j(x_i)$, …, $e_n(x_i)$, $b_n(x_i)$,

where

$d_j(x_i)$: time when a key is pressed down, it is presented as either a 'dot' or 'dash', the duration of jth Morse code element of the input character x_i.
$b_j(x_i)$: time when a key is held up, it is presented as one of two spaces: the space between elements of one character, or the space between characters, the duration of jth space of the input character x_i.
n: the total number of Morse code elements in character x_i.
$m_j(x_i)$: a dot or dash which is recognized from $e_j(x_i)$.
If $b_j(x_i)$ is recognized as a character space, then $b_k = b_j(x_i)/3.0$; otherwise, $b_k = b_j(x_i)$.

Space Recognition

The space recognition process is used to identify the space between characters (dot-dash space) and the isolated elements of a Morse code character (character space). Dot-dash space exists within the elements of a character, while character space exists between complete characters. The procedure for space recognition is given below:

1. Assign index j=1.
2. If $b_j(x_i) < 2S_1$, then go to step 3, otherwise go to step 4.
3. Set j=j+1 and save $e_j(x_i)$, then go to step 2.
4. If $b_j(x_i) > 5S_1$, then it is the end of a word, otherwise go to step 5.
5. The key-in Morse elements in character x_i are encoded as $e_j(x_i)$ for j=1 to n.
6. To separate the next character, if any, go to step 1.

The initial space length, S_1, is calculated from the first nine values of silent elements. These nine values are sorted in descending order and then compared. Conversely, a smaller value is represented as a short value. Once all long values have been collected, the sum of their values is divided by 3 (based on the definition of the silent ratio) and added to the sum of the short values. The resulting value is then divided by the total number of elements to obtain the initial space S_1. The formula for this calculation follows:

$$S_1 = \frac{\text{(sum of the long silent values)/3} + \text{sum of the short silent values}}{\text{total number of elements}}$$

We use the following Morse code digital stream as an example to illustrate this procedure: 80 <u>107</u> 72 <u>136</u> 72 <u>1569</u> 110 <u>135</u> 321 <u>114</u> 243 <u>141</u> 73 <u>110</u> 251 <u>1249</u> 80 <u>1322</u>. Odd position data designate a tone value while even position data (underlined) designate a silent value. The first nine silent values in our example are <u>107</u> <u>136</u> <u>1569</u> <u>135</u> <u>114</u> <u>141</u> <u>110</u> <u>1249</u> <u>1322</u>. The descending order of these nine values becomes <u>1569</u> <u>1322</u> <u>1249</u> <u>141</u> <u>136</u> <u>135</u> <u>114</u> <u>110</u> <u>107</u>. As can be seen, the first three values in the sample (<u>1569</u>, 1322 and 1249) are more than twice as large as the others; therefore, they must be long silent values. The remaining values then belong to short silent values. Thus, in this sample the initial space length, S_1, is set to 236. Consequently, once the initial space length has been determined, each subsequent silent element can be recognized as a dot-dash space or a character space.

Tone Recognition

The tone recognition process is used for identifying the tone element, either a dot or dash. Before an unidentified character can be recognized from a series of Morse code elements, the tone_base of the elements must first be determined. Once a tone-base value has been established, each subsequent incoming element can be determined to be either a dot or a dash. Overall, the process to determine the initial tone_base value is similar to that of determining the initial space length as discussed above. The only difference is that instead of taking the first nine values of silent elements, it is the first nine values of the tone element set that are taken as a reference. Once obtained, the values of this reference are sorted and compared, and the average is assigned as the initial tone-base value. When a tone element set is unacceptable as a reference because long and short values cannot be extracted, the next tone used to calculate the new reference values. Upon having determined the initial tone-base, each subsequent tone element is read, one by one, and can immediately be determined to be either a dot or dash: If the element is more than twice as large as than the tone_base, it is represented as a dash. Otherwise, it is represented as a dot. The averages of the long values and short values are used to calculate dash_base and dot_base. Finally, the tone_base is obtained from the ratio of tonesum to toneratio where tonesum is the sum of dot_base and dash_base and toneratio is the ratio of dash_base to dot_base.

Using the above example, the first character set is 80, 72 and 72. Since 80 and 72 are neither more than twice as large as, nor less than half as small as any other tone value, they cannot be determined to be long or small values. The second character set, 110, 321, 243, 73 and 251 must be used instead. Since values 110 and 73 are short tone values, and values 321, 243 and 251 are long tone values, the second tone element set is taken as reference values. Then, the initial tone_base values can be calculated. The ‘dot’ and ‘dash’ are taken from the third tone element, Dot: 110, 73, Dash: 321, 243, 251. In this example, the dot_base and dash_base are 91 and 271, respectively. The initial tone_base is 121.87.

Character Recognition

Because each tone element has already been recognized as either a dot or dash by the tone recognition process, once a character space value has been registered in tone_buffer, these tone buffer elements can be sent to character recognition. If in the character recognition process the tone element set matches a code set from the Morse code table, then a direct translation is performed. Otherwise, the tone element set must be translated by performing a minimum distance calculation as follows. Each tone element value in an unknown tone element set is divided by the tone_base of the previous tone element set, which calculates the distance between each tone value and code elements in each character in the Morse code. The character with the minimum Euclidean distance is subsequently selected as the value of the unknown character. The procedure for determining the minimum Euclidean distance is the following. First, each tone element, $e_j(x_i)$, is divided by the tone_base, $e_j(x_i)$/tone_base, for j=1 to n. Next, the roots of the sum of the square distances between the new tone element, $e_j(x_i)$, and each character from the Morse code table is calculated. Finally, the character in the Morse code table that has the shortest Euclidean distance is determined to be the unknown character.

Adaptive Processing

The Least-Mean-Square (LMS) algorithm is used to predict an unstable key release time. Let the input vector to the system be denoted by X_k and the desired scalar output be d_k. These processes are assumed to be related by the equation

$$d_k = X_k^T W_k^* + e_k$$

where e_k is a zero mean independent Gaussian sequence,and independent of the input process X_k. W_k^* is randomly varying according to the equation

$$W_{k+1}^* = aW_k^* + Z_k$$

where a is less than but close to 1 under non-stationary conditions (under stationary condition a = 1), and Z_k is an independent zero mean sequence, independent of X_k and e_k, with covariance $E\{Z_k Z_j^T\} = \sigma_z^2 I \delta_{kj}$, δ_{kj} being the Kronecker delta function. The input process X_k is assumed to be a zero mean independent sequence with covariance $E(X_k X_k^T) = R$, a positive definite matrix [10].

The LMS algorithm computes a set of weights W_k that seeks to minimize $E(d_k - X^T_k W_k)^2$. Each adaptive weight W_k is of the form

$$W_{k+1} = W_k + \mu X_k \varepsilon_k$$

where

$$\varepsilon_k = d_k - X^T_k W_k$$

and μ is the step-size parameter that controls the speed of convergence as well as the steady-state and/or tracking behavior of the adaptive filter.

The LMS algorithm used in the system serves to cleverly convert the ‘space’ length to predict an unstable key release time. During space recognition, the character space is isolated, divided by a constant (3.0) and the resulting value is then sent to adaptive processing. For the dot or dash space, the space element value is sent directly to the adaptive processing. An algorithm with nine weights was used in this paper.

Tone Base Adjustment

Because a disabled person usually generates an unstable Morse code series, the value to be identified as a dot or dash has to be recalculated based on the preceding tone element. Therefore, in this research, the tone_base value was modified as each tone element entered the system. Each tone element value was compared with the tone_base. If the tone element value was larger than the tone_base, it was represented as a dash; otherwise, it was represented as a dot. When a dash was obtained, the dash_base could be updated by taking the average of the dash value and the dash_base. Similarly, a new adjusted dot_base was obtained from the average of the dot value and the previous dot_base. Then, as described above, the ratio of new tonesum to new toneratio was the new tone_base. The new adjusted toneratio is the ratio of dash_base to new dot_base or the ratio of new dash_base to dot_base. The new adjusted tonesum is the sum of dash_base and new dot_base or the sum of new dash_base and dot_base. This procedure is repeated for every new incoming value so that the dash_base, dot_base, tone_sum, toneratio and finally the tone_base is constantly updated to adjust for a variation in typing speed.

In the previous example, tone_base is 121.87, dot_base is 91, and dash_base is 271. Therefore, since the first tone element, 80, is smaller than the tone_base, 121.87, the tone element 80 is represented as a dot. Thus the new dot_base is (80+91)/2 = 85. The new adjusted toneratio is 271/85 = 3.19, and the new adjusted tonesum is 271+85=356. The new adjusted tone_base is 356/3.19=111.

3. RESULTS AND DISCUSSION

Test data from two disabled participants (Disn) was examined to investigate the efficiency of the proposed method. The participants have been diagnosed with cerebral palsy (participant 1, P1) and a spinal cord injury with incomplete quadriparesis (participant 2, P2). Each typed 100 characters in 15 test samples, numbered from Dis01 to Dis15 in Table 1.

Since the Luo and Shih system [2] is restricted to a variation of typing speeds ranging from 0.67 to 2.0 times the typing speed of the preceding character, it was not intended for comparison with this study. Instead the proposed method was compared against Shih and Luo’s improved system [3] and a system developed by Yang [9]. Table 1 illustrates that the proposed method consistently produces the highest number of matches for all the tested problems. The average number of matches for SL, Yang, and the proposed method are 70.67, 85.50, and 89.27. This can be explained as follows. A Morse code time series is generally unstable, in speed. An unstable typing speed can generate two kinds of errors: a space recognition error and a tone recognition error. Maintaining precise intervals is difficult even for abled persons, not to mention disabled persons. Generally speaking, a person's typing is constant over a short period of time. That is, the person's present typing rate is similar to the typing rate of the immediately preceding several words. Because each person has his or her individual typing speed, the dot and dash values cannot be set to a default value. Therefore, in the proposed method, the dot_base, dash_base, and tone_base are continuously recalculated to predict the next space and tone length as each tone element is read in.

Table 1. Comparison of the number of matches (out of 100) for the two disabled participants for the three methods.

Problems	P1			P2			P1&P2(average)		
	SL	Yang	NEW	SL	Yang	NEW	SL	Yang	NEW
Dis01	70	93	93	79	95	98	74.5	94.0	95.5
Dis02	66	78	83	81	90	93	73.5	84.0	88.0
Dis03	75	87	92	81	94	97	78.0	90.5	94.5
Dis04	70	89	92	73	93	93	71.5	91.0	92.5
Dis05	71	88	94	67	74	76	69.0	81.0	85.0
Dis06	71	89	91	75	95	99	73.0	92.0	95.0
Dis07	73	83	86	74	88	89	73.5	85.5	87.5
Dis08	70	90	92	81	94	95	75.5	92.0	93.5
Dis09	79	90	96	78	91	95	78.5	90.5	95.5
Dis10	72	86	92	77	90	93	74.5	85.0	92.5
Dis11	77	77	92	70	94	96	73.5	85.5	94.0
Dis12	73	79	95	82	95	94	77.5	87.0	94.5
Dis13	66	84	88	75	94	94	70.5	89.5	91.0
Dis14	62	88	92	32	44	47	47.0	66.0	69.5
Dis15	68	90	93	32	45	48	50.0	67.5	70.5
Average	70.87	86.07	91.40	70.47	84.93	87.13	70.67	85.50	89.27

Legends:
SL: Shih and Luo's method [3].
Yang: Yang's method [9].
NEW: the proposed method.
P1: participant 1.
P2: participant 2.

The Friedman test is a nonparametric counterpart of the parametric two-way analysis of variance tests and is used to compare the total matches of the recognition methods when the distribution of the underlying population is not specified. The null hypothesis is that all three of the methods have equal median total matches. The alternative hypothesis is that the three methods do not all the same median told methods. After using the Friedman test to compare the three methods, we rejected the null hypothesis at the .05 significance level.

Following the multiple comparisons test given in Conover [12], the total matches of the three methods were ordered in an array, and a rank was assigned to each corresponding to its order. The rank sums of NEW, Yang, and SL are 45.0, 30.0, and 15.0 for the test problems. If the rank sums of any two methods are greater than 2.02 units apart (with α = .05), they may be regarded as having unequal medians. Therefore, it can be concluded that the proposed method here is statistically superior to both the Yang and SL's methods.

4. CONCLUSIONS

Morse code has been shown in the literature to be an attractive candidate as an adaptive tool for disabled persons whose hand coordination and dexterity are severely impaired, thus limiting their ability to communicate via computer technology. Due to the fact that maintaining a stable typing rate is a challenge for the disabled, an improved method with a higher character recognition rate is desperately needed. Since typing for the disabled is more difficult than for the people without physical handicaps, it causes the disabled to tire more easily, to the detriment of a constant typing rate. In this paper, we experimented with the LMS algorithm and a new adjustment method for the adaptive Chinese phonetic Morse code recognition to address the input problem for the disabled. Experimental results revealed that the recognition rate of the method proposed here was superior to alternative methods in the literature [3, 9]. With these encouraging findings, the application of Morse code to control household electrical equipment is worth discussing and implementing in the next step of this project.

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