

Finger Drift Compensation (FDC) Model for Braille Input

Parinyarat. Tuchinda, Atiwong. Suchato, and Proadpran. Punyabukkana

Abstract— As the technology advances, touchscreen device became the most popular at the present time. This paper proposes the Finger Drift Compensation (FDC) Model for braille input and translation of braille characters to text in Thai for visually impaired with touch screen device. The model is needed for people with visual disability to improve accuracy braille sequence of touchscreen device and this paper proposes method that compensate for finger drift and this method has the effect of following a user's touches over time. With FDC model, coordinates are input into a device with multi-touch, based on the six dots of the braille code of brailier, which each set of coordinates represents one character. Sets of coordinates are grouped based on their timings so that the coordinates in each group are hypothesized as belonging to the same character. This paper is designed such that it learns the user's typing behavior including individual typing rhythm and drifting patterns in order to translate the inputted braille keystrokes to the corresponding Thai characters. The experimental result from four blind participants showed 95.14% accuracy when using the proposed method.

Keywords—Drift Model, Accessibility, Visual Impairment, Text entry, Touchscreen

I. INTRODUCTION

NOWADAYS, Touchscreen technology [13] was first developed in the late 1982's. As time progressed, touchscreen devices have become famous in the communication via the internet such as youtube, facebook, twitter, line, whatsapp etc.. Touchscreen is a method of input with finger or stylus. The user can slide the finger freely and can choose the option or function by click on touchscreen. Most of Touchscreen technology were developed as mobile, tablet, notebook, atm, tv, GPS systems, game, watch, Self Service Ticket Kiosk, exercise machines etc.. Unfortunately, touchscreen can present to visually impaired. Touchscreen devices remains a significant problem for users who are visually impaired. Because users will not be recognized as position of keypad or control buttons are fixed location on touchscreen, which is difficult to accessible by visually impaired. The touchscreen devices are popular and accepted

Ms. Parinyarat. Tuchinda is with Department of Computer Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330 Thailand (e-mail: Parinyarat.T@student.chula.ac.th).

Assoc. Prof. Dr. Atiwong. Suchato is with Department of Computer Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330 Thailand (e-mail: Atiwong.S@chula.ac.th).

Assist. Prof. Dr. Proadpran. Punyabukkana is with Department of Computer Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330 Thailand (e-mail: Proadpran.P@chula.ac.th).

among the visually impaired is Iphone which has the function called Voice Over[14]. The Voice Over is screen reader, which is program to translate information into speech, the user can be heard information through earphones or speakers on Iphone or Ipad. However, this access is still a problem when the users require large documents or long text, it may take longer to print.

II. LITERATURE REVIEW

In previous works, Input Finger Detection (IFD), [2] a novel technique for nonvisual touchscreen input, and its application, the Perkins Braille text entry method. With IFD, signals are input to a device with multi-point touches, where each finger represents one bit, either touching the screen or not. Similarly, Braille Touch [1] application proposed strategy that compensated finger drift by using an exponential moving average [10,11] to recalculate the position of the soft keys after each touch. However, their research did not attentive in the subject of the problem of finger motion while typing on touchscreen by a visually impaired. Other accessibility touch screen technology for the visually impaired, Slide Rule, BrailleType, TypeInBraille and No-Look Notes [3,4,5,6] is braille-based typing application for mobile devices with a small touchscreen but users may not the convenience of printing long documents, because the screen is small, the text entry is difficult. Apple's VoiceOver text entry solution relies on a soft keyboard in which the users focus the desired key by touching it. On the other hand, VoiceOver typically uses a QWERTY soft keyboard layout; hence, it features a large number of targets, making it difficult to find a specific letter.

This study propose a compensation model for accommodate the movement of the fingers, wrists, arms, and other factors as a result of long-term typing on touch screen for braille input. The design is based on the brailier text entry method. This paper is structured as follow. Section II explains Braille Character and the brailier text entry method. Section III describes the proposed method. Section IV illustrates the experimental framework. The last section consists of conclusion and future work.

III. BACKGROUND

Braille[7,8] is a writing system widely used by the blind around the world to read and write, it was discovered and developed by Louis Braille. Braille characters consist of six convex points arranged vertically into a braille cell. The braille cell has 2 rows. The first row of braille cell represents

braille code 1-2-3 and the second row represents braille code 4-5-6. The 6 dots can be converted into 64 different forms to replace the symbols in different languages. The braille alphabet is shown in Fig. 1. The blind can read braille with a finger touch at different point or the braille code which represents each character. In order to write or type braille, the blind uses a writing equipment called a slate and stylus to create a convex point along the position of the sentence determined from right to left. For examples, positions 1 2 4 5 encode the letter “n”, while positions 1 3 encode the letter “v”. In Thai braille [16] is shown in Fig. 2.

a	b	c	d	e	f	g	h	i	j
•	••	•••	••••	•••••	••••••	•••••••	••••••••	•••••••••	••••••••••
k	l	m	n	o	p	q	r	s	t
•••	••••	•••••	••••••	•••••••	••••••••	•••••••••	••••••••••	•••••••••••	••••••••••••
u	v	x	y	z					w
••••	•••••	••••••	•••••••	••••••••					•••••••••

Fig. 1 The English Braille characters where black dots represent raised dots.

ก	ข	ฃ	ค	ฅ	ฉ	ช	ฌ	ญ	ฎ	ฏ
••	•••	••••	•••••	••••••	•••••••	••••••••	•••••••••	••••••••••	•••••••••••	••••••••••••
ณ	ด	ต	ถ	ท	ธ	ฒ	ณ	ด	ต	ถ
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น	บ	ป	ผ	ฝ	พ	ฟ	ภ	ม		
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ย	ร	ล	ว	ศ	ษ	ห	ฬ	อ	ฮ	
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Fig. 2 The Thai Braille characters where black dots represent raised dots.

For typing the Braille, the blind will use the equipment called the brailier [8,15], which has similar appearance as the normal typewriter, the difference is only that the brailier’s keyboard consists of 6 keys represented the braille code, a backspace, a space bar and a line spacer. The brailier is shown in Fig. 3. The braille characters are made by pressing one or more keys with 2 hands. With left hand, the pattern of braille code 1 2 3 is represented by index finger, middle finger and ring finger respectively. With right hand, the pattern of braille code 4 5 6 is represented by index finger, middle finger and ring finger respectively. The pattern is shown in Fig. 4.



Fig. 3 The Brailier has six keys corresponding to the six dots



Fig. 4 The pattern of braille code is represented by six fingers.

IV. PROPOSED METHOD

The proposed method are divided into two parts. Learning of the user's typing behavior from gathering and storing data to find out the statistical methods (forecasting methods) [10,11], which is the most suitable for the design of Drift Model will be in the first part. The second part is shown in this section. The second part will discuss the technical and statistical methods used to analyze the distribution of the data, the variability of the data, and the trends of the data in order to design the model used to compensate for the movement. The process is divided into six steps whose details will be elaborated in the next subsections.

A. Braille Input (coordinates)

The coordinates are input into a device with touchscreen device, which each set of coordinates represents one character. Set of coordinates are grouped based on their timings so that the coordinates in each group are hypothesized as belonging to the same character.

B. Set of Coordinates

The set of coordinates are grouped based on their timings. In this research, the timing defined as 150 msec. This figure was found from learning of the user's typing behavior in the first part. The set of coordinates (Blue circle) is shown in Fig. 5.



Fig. 5 The group of green circle is the set of reference point.

C. Drift Model

In the next steps, the study uses mathematical projection model and statistical methods to calculate the set of reference point after each touch. In which from the preliminary study found out that there occurs the shift of fingers in different direction and likewise causes the distance between fingers to change. It also cause the change in distance between both hands and the angle of the wrist that changes. From various factors found, Drift Model was designed and divided into 2 parts, which are:

- The statistical methods [10,11] - used to predict the coordinates of the finger when the shift of finger or wrist occurs vertically (up – down), horizontally (left – right) or making an angle.
- Pythagoras[9] - used to calculate the distance between two finger. For example are shown in Fig. 6. C is the distance between two finger . Xa means the x-coordinate of point A. Ya means the y-coordinate of point A. The horizontal distance "a" is $(X_a - X_b)$ and the vertical distance "b" is $(Y_a - Y_b)$.

In this model , we set the radius of each circle. The radius is 50 pixel. This figure was found from learning of the user's typing behavior in the first part. The distance between two finger is a measure of the movement of the fingers. If the finger shift leaving the circle, show that movement more than 50 pixel. Then the model will reset the new reference point by the appropriate statistical methods.

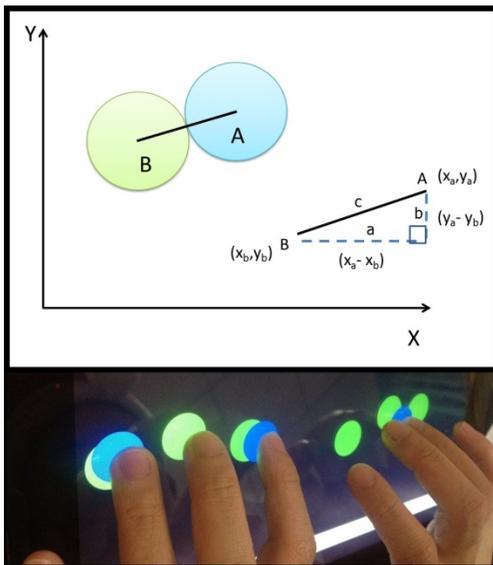


Fig. 6 The distance between two finger was calculated by Pythagoras.

D. Set of Reference Point

This step, we will compare between the set of reference point and the set of coordinates, which are grouped based on their timings , which the couple of coordinate have minimal distance is determined the same position , which is pressed by the same finger. The set of reference point (Green circle) is shown in Fig. 6.

E. Set of Position of the Keys

The size of set of coordinate is equal to the size of set of position. In this step, we expect to know the position of each

coordinates of the set of coordinate. The set of position is replaced braille code and is translated to character in next step.

F. Mapping and Translation

The last step, we will match position of finger with the braille code to convert a regular character. For example, a user enters position 1 and 2 with the left hand and enters position 4 and 5 with the right hand by touching the screen. The letter “n” is translated from braille code. The example is shown in Fig. 7.

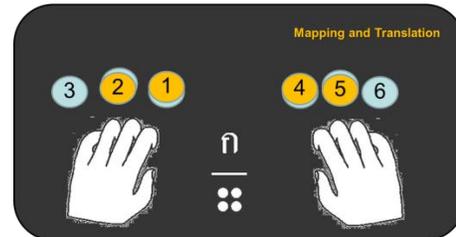


Fig. 7 Example : Press 1,2,3 and 4 simultaneously to get which is the Braille character for “n”.

V. EXPERIMENTAL FRAMEWORK

A. Experimental Setup

To evaluate FDC model on a tablet , we compared the Braille Touch in nonvisual touch screen text entry. We recruited 4 participants (two females, two males, average age 35) for the study. Participants were recruited from the Ratchasuda Center for the visually impaired. All users are also proficient at typing on a QWERTY keyboard and assistive technology (screen readers , voice over). For this experimental task we used the Acer Iconia A5 touch screen device, which runs on android operating system. This device has a 10 inch capacitive touch screen with 10 multi-touch support.

First, participants spent 45 minutes learning the system. Experimenters taught the participants how to explore, enter characters and place the wrist while typing. Participants were required to demonstrate their grasp of each new action, and were encouraged to ask questions. During training, we taught participant the basics and wrist position while typing until he/she independently typed braille character on touchscreen device. After the training, we started experiment by informing participants to type sentence (20 sentence both Thai and English) . The system recorded each coordinate of keys and its time stamp. We allowed users to type text in the second round in braille note taker for the accuracy of the corresponding sentences due to the fact that users do not know the spelling. After completing the task, we conducted an interview. Comment and suggestions were collected in order to improve our system The preliminary experiment is shown in Fig. 8.

B. Evaluation Criteria

This step is divided into two experimentals. The details are listed below.

- 1)EXP1 : Analysis of finger drift

Initially , we learn the user's typing behavior from gathering and storing data. We recruited 20 participants (twelve females, eight males, average age 35) for the study. We started gathering and storing data by informing participants to type character and sentence on touch. The system recorded each coordinate of keys and its time stamp. And then we design the preliminary experiment for comparative study of four forecasting methods[10,11] – moving average, exponential smoothing , long – term linear trend projection, and trend-adjust exponential smoothing – used to predict a set of reference point. We started to learn the printing habits and the distance between the fingers with experiment by informing users to type sentence on touch . The system recorded each coordinate of keys and its time stamp. In this step, we calculated performance of forecasting using the the mean squared error (MSE) [10] , which is represented the difference between the actual observations and the observation values predicted by the model, is used to determine the extent to which the model fits the data and whether the removal or some explanatory variables, simplifying the model, is possible without significantly harming the model's predictive ability. The mean squared error (MSE) can be calculated from:

$$MSE = \frac{\Sigma(\text{Error}^2)}{n} \quad (1)$$

where Error is forecast error (trend coordinate - actual coordinate) and n is number of trend coordinate.

2)EXP2 : Measurement the Performance of Translation

In this experiment, we considered typing accuracy and used Braille Touch (exponential smoothing model) as the baseline. We calculated accuracy using f-measure [12] , which is a measure of a experiment's accuracy. It considers both the precision (PC) and the recall (RC) of the test to compute the score: PC is the number of correct results divided by the number of all returned results and RC is the number of correct results divided by the number of results that should have been returned. The f-measure can be interpreted as a weighted average of the precision and recall, where an f-measure score reaches its best value at 1 and worst score at 0. The f-measure can be calculated from:

$$PC = \frac{\text{correct}}{(\text{output-length})} \quad (2)$$

$$RC = \frac{\text{correct}}{(\text{reference-length})} \quad (3)$$

$$F - \text{measure} = \frac{(PC \times RC)}{(PC + RC)/2} \quad (4)$$

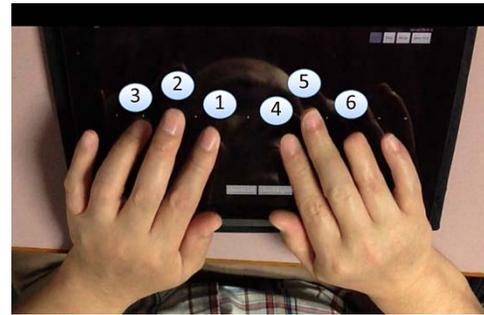


Fig. 8 The preliminary experiment

VI. RESULTS AND DISCUSSION

From gathering and storing data, we found characteristic of fingers and hands such as spread of fingers ,straight shape, bent shape, distance between the fingers and distance between wrists are changed and stretch the forearm over time. In EXP1, four forecasting methods were used to predict 325 keys press (100 characters,325 coordinates). By comparison, we found that the long – term linear trend projection method gives the most accurate forecast with the smallest MSE are considered good because our study expected MSE is small (if the squared error is small then the accuracy of forecast the position of keys will be high as well) as shown in Table I.

TABLE I
THE RESULT OF THE MEAN SQUARED ERROR (MSE)

Method	MSE
Moving average	1901.49
Exponential smoothing (Baseline)	1481.18
Long – term linear trend projection (Proposed)	1071.16
Trend-adjust exponential smoothing	2531.34

In EXP2, we considered typing accuracy and used Braille Touch (exponential smoothing model) as the baseline. We used the performance criteria aiming to measure accuracy of the system as equation 2 to equation 4. The results are shown in Table II and Table III.

We reported the f-measure for the all session. The expert braille typists on the tablet (exponential smoothing model) averaged 81.25% and 95.14% (long – term linear trend projection model), respectively. The results showed that using FDC model outperformed Braille Touch for braille input and translation of braille characters to text in Thai for visually impaired with touch screen device. The example of translation is shown in Fig. 9. As exponential smoothing is the statistical method that can be applied to time series data, either to produce smoothed data for presentation, or to make forecasts. Exponential smoothing can be used with any discrete set of repeated measurements. However it is inappropriate when using with changeable data. Because this method has the assumption that the average is constant. In the study trend projection by linear regression [11] (The long – term linear trend projection method) can be applied to data with linear trend pattern and long term. In statistics, regression analysis is a statistical technique for estimating the relationships among variables. FDC model uses the long – term linear trend

projection method, which is adjusted to smooth the mean and trend next keys after each touch. This method uses the underlying long-term trend of data to forecast its future values. Linear regression implements a statistical model that, when relationships between the independent variables and the dependent variable are almost linear, it shows optimal results in recalculation of the soft keys after each touch.

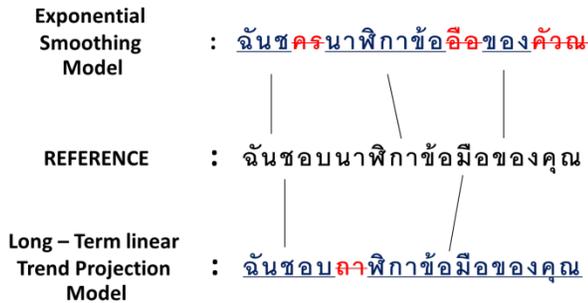


Fig. 9 An example of translation

TABLE II
THE RESULT OF F-MEASURE FOR TRANSLATION BRAILLE TO TEXT BY EXPONENTIAL SMOOTHING MODEL

Metric	Exponential Smoothing				Average
	A1	A2	A3	A4	
Precision	75.65%	90.83%	83.47%	81.67%	82.91%
Recall	70.73%	88.62%	79.67%	79.67%	79.67%
F-measure	73.11%	89.71%	81.53%	80.66%	81.25%

TABLE III
THE RESULT OF F-MEASURE FOR TRANSLATION BRAILLE TO TEXT BY LONG – TERM LINEAR TREND PROJECTION MODEL

Metric	Long – Term Linear Trend Projection				Average
	A1	A2	A3	A4	
Precision	93.28%	97.54%	97.52%	95.08%	95.86%
Recall	90.24%	96.75%	95.93%	94.31%	94.31%
F-measure	91.74%	97.14%	96.72%	94.96%	95.14%

VII. CONCLUSION

Translation from Thai writing to braille printing characters, we then discuss the design implications of this study for our model, especially regarding to improve accuracy. In evaluation, the study showed that FCD model outperforms

braille touch. FCD model is more accurate in the first as well as the final sessions of the study with 95.14% f-measure. In future works, we plan to develop hybrid model for each user’s fingers and to use this information for the point detection. Our choice of tracking constants was somewhat arbitrary. Instead, we plan to learn the printing habits and the distance between the fingers. In text entry, the decoding algorithm receives negative reinforcement from the users when the backspace key deletes a user’s input. FDC model can also be improved by adding support for word-level automatic corrections and better audio feedback. For example, when a user enters a space, the previous phrases should be converted to a speech by automatic text-to-speech system.

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