DETERMINING THE EFFECTIVE AUTHENTICATION FACTORS USING TOUCHSCREEN PHONES' RANDOM NUMERIC KEYPAD

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การกำหนดปัจจัยที่มีประสิทธิภาพในการยืนยันตัวตนโดยใช้มือถือที่มีระบบหน้าจอสัมผัสที่มีแป้นตัวเลขแบบสุ่ม

น.ส.นารีรัตน์ เบญจพัฒนมงคล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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นารีรัตน์ เบญจพัฒนมงคล : การกำหนดปัจจัยที่มีประสิทธิภาพในการยืนยันตัวตนโดยใช้มือถือที่มีระบบหน้าจอสัมผัสที่มีแป้นตัวเลขแบบสุ่ม. (DETERMINING THE EFFECTIVE AUTHENTICATION FACTORS USING TOUCHSCREEN PHONES' RANDOM NUMERIC KEYPAD) อ.ที่ปรึกษาหลัก : ร.ศ. ดร.ภัทรสินี ภัทรโกศล

เนื่องจากปัจจุบันมีการใช้มือถือระบบหน้าจอสัมผัสเป็นจำนวนมาก โปรแกรมมือถือก็ได้มีการเพิ่มขึ้นตามลำดับ ทั้งนี้สถาบันการเงินมีการจัดทำโปรแกรมมือถือของบริษัทเอง เพื่อที่จะรองรับการใช้งานของลูกค้า และทำให้การเข้าถึงบัญชีของลูกค้าสะดวกยิ่งขึ้น ณ ปัจจุบัน ลูกค้าของสถาบันการเงินในประเทศไทยนั้นสามารถ เข้าถึงบัญชีของตน ผ่านโปรแกรมมือถือได้ 2 วิธีด้วยกัน ซึ่งก็คือ การใช้รหัสตัวเลข 6 หลัก หรือ การใช้ลายนิ้วมือ

ดังนั้นเพื่อเป็นการหาปัจจัยเสริมความปลอดภัยในการเข้าถึงบัญชีของลูกค้าผ่านโปรแกรมมือถือด้วยการพิมพ์ตัวเลข การวิจัยนี้จึงมุ่งเน้นหาปัจจัยที่มีประสิทธิภาพในการยืนยันตัวตนบนมือถือที่มีระบบหน้าจอสัมผัสที่มีแป้นตัวเลขแบบสุ่ม เนื่องจากแป้นพิมพ์ที่มีตัวเลขสุ่มนั้นจะช่วยเสริมการป้องกันการลอบดูรหัสระหว่างการพิมพ์บนมือถือ รวมถึงการสุ่มรหัสจากรอยคราบนิ้วมือที่ติดบนหน้าจอมือถือ จากการวิจัย ปัจจัยที่มีประสิทธิภาพในการยืนยันตัวตนนั้นคือ ปัจจัยรวมซึ่งประกอบด้วย เวลาระหว่างการกด (flight times) เวลาที่กด (dwell times) ยอดรวมของเวลาที่กด (total dwell time) และ อีก 2 ปัจจัยที่ผู้เข้าร่วมกำหนดเองซึ่งก็คือ เพศ และ จำนวนนิ้วที่ใช้ในการทดสอบ ทั้งนี้ ในการวิจัยนี้จำนวนประชากรของปัจจัยที่ผู้เข้าร่วมกำหนดเองนั้นไม่เท่ากัน แต่การวิจัยไม่ได้วิเคราะห์ผลกระทบของประเด็นเหล่านี้ต่อความแม่นยำในการกำหนดตัวตน ปัจจัยที่มีประสิทธิภาพในการยืนยันตัวตนโดยใช้แป้นพิมพ์ตัวเลขที่มีตัวเลขแบบสุ่มนั้น จะสามารถนำมาประยุกต์ใช้กับการพิมพ์รหัสตัวเลขเพื่อเข้าถึงบัญชีธนาคารผ่านมือถือ อันเป็นการเพิ่มความปลอดภัยในการเข้าถึงบัญชีธนาคาร

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For the past decade, the increased usage of touchscreen phone devices has driven the mobile application market that prompted the financial institutes to release their own mobile banking applications to better serve their customers. To date, there are two ways a Thai bank customer can access his/her account(s) via the mobile banking application i) using a 6-digit Personal Identification Number (PIN) or ii) using fingerprint.

To help to strengthen the current PIN-only authentication which may be exposed to smudge and shoulder-surfing attacks, the research studied and determined the effective authentication factors using a random numeric keypad. The results from the research indicated that the most effective authentication factors or features among those considered are in fact a combination of the factors which are flight times, dwell times, total dwell time and 2 user-defined values (number of fingers used and gender). However, it is to be noted that there is unequal sample size for each of the user-defined values and this research did not investigate how such occurrences impact the overall accuracy. These factors can be applied in the development of stronger keystroke dynamic model for PIN-based authentication using the random numeric keypad for mobile banking environment.

Field of Study:	Computer Science and Information Technology	Student's Signature ....
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Finally, I would like to express my eternal gratitude to my family for their support and encouragement throughout my course at the university.

Nareerat Benjapatanamongkol

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CHAPTER 1 INTRODUCTION

1.1 Background and Importance

According to DTCC survey ("New DTCC Risk Survey Reveals Growing Concerns over Brexit's Systemic Implications," 2018), cyber risk was ranked first in risks to financial stability. Cyber risk can be from both cyber-attack (e.g. phishing, malware, etc.) and non-cyber-attack (e.g. software update, natural disaster, etc.). Cyber risk mentioned in this research refers to cyber-attack to gain access to the confidential information of the financial institutes such as banks.

Despite Banks have employed various measures such installation of antivirus software, blocking unauthorized online access with firewalls and using encryption programs, cyber-attackers still find ways to steal the users' bank logins and credit card information (Ketchum, 2017), for instance, messages during the online session and OTP messages in the 2-factor authentication can be incepted by the malware or malicious mobile applications.

Per IMF Working Papers in 2018 by Bouveret (Antoine, 2018), data on cyber risk to the financial sectors are scarce as companies do not have incentives to report them; and there are no reporting standard for the data on cyber risk. Moreover, disclosing data that are reported to local regulators may have national security concerns. Besides, the U.S. just revised their SEC guidance in 2018 in regard to disclosure of cyber-attacks, addressing on how and when the listed firms should disclose such information to the investors. Considering reputational and systematic risks involved, it is inevitable that there is a scarcity of complete data on cyber incidents in the financial sectors.

As such, it is difficult to determine the cyber losses from cyber-attacks as the only available information are from the incomplete and inconsistent public and commercial datasets. The financial losses known are the direct loses albeit the indirect losses such as reputational losses have far more lasting impact. From ORX News (Operational Riskdata eXchange Association, largest operational risk association in the financial services sector established in 2002) (Antoine, 2018), during the period of 2009-2017, there have been 341 cyber events on the financial sectors with a third of them incurring direct financial losses. All economies (developed, developing and emerging markets) are targeted by the cyber-attackers with successful attempts occurred in more than 50 countries in recent years. Since there is no relationship between financial losses from cyber-attack and size of financial institution (Antoine, 2018), all financial institutes are exposed to cyber-attack risk equally and should invest in IT security system to prevent financial losses.

Nonetheless, with increasing adoption of mobile banking in Thailand ("Thailand leads mobile banking penetration," 2019; "Thailand Tops Global Digital Rankings," 2019), it would be beneficial to the clients if there are ways to strengthen the current authentication system on the touchscreen smartphone devices (smartphones). To date, there are basically two ways for a user to “log-in” the mobile banking i.e. by fingerprint and by 6-digit Personal Identification Numbers (PINs). PINs were first used in 1967 (J. Bonneau, 2012) in by Barclays Bank’s ATM machine. In those days, PINs were assigned by banks and hardcoded onto the ATM card. It was in 1980s that the customers were allowed to choose their own PINs as new PIN system were implemented.

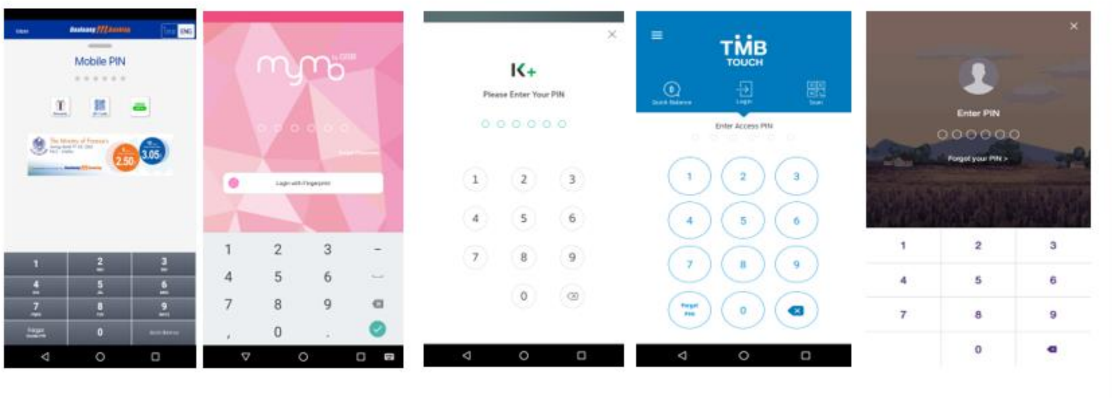


Figure 1. Examples of current mobile log-in page of some Thai banks using PINs
(From left: Bangkok Bank, Government Saving Bank, Kasikorn Bank, Thai Militatry Bank, Siam Commercial Bank)

In the normal selection of banking PINs, the customers are warned not to use publicly known or easy to guess numbers. Nonetheless, some customers may still use a combination of easily-guessed numbers as their PINs (J. Bonneau, 2012). Consequently, PIN-only authentication may not be adequate to protect the users' data from cyber-attack in today's fast paced technological advances that may further aid the cyber hackers. There are also risks from shoulder surfing from malicious actors who may try to see the users' screens while the users type their passwords or risk from smudge attacks if the malicious actors could get hold of the users' unlocked smartphones or smartphones with no imposed security setting.

Some users have adopted fingerprint authentication (physical biometrics) in smartphones due to ease of use. The capacitive fingerprint scanners, that can reproduce 2D images, embedded in most smartphones are limited in size. Hence, the users have to register several partial fingerprints to be stored as a template for authentication. Nonetheless, fingerprint authentication in mobile phone is still prone to spoofing and identity theft via fake finger (A. Roy, 2017) with increased attack success when partial fingerprints of multiple fingers data are available. In addition, there had been reports of banking system being hacked as such there is a possibility that some malicious actors may obtain the users' fingerprint data.

Meanwhile, the new fingerprint scanner technology ("Ultrasonic fingerprint scanners: how do they work?,"), the 3D ultrasonic fingerprint scanner can reproduce 3D images that are much more detailed than the 2D images. However, the scanner has just been around in 2019 and its effectiveness against replication is yet to be proven. On the other hand, behavioral biometric personal data (e.g. keystroke dynamics) is deemed less privacy-invasive (can be changed and not a permanent identification) with lower deployment cost and would not be as easy to replicate compared to PIN-only authentication.

In keystroke dynamics analysis, the most common features are the time-related features such as the dwell time (the time duration of each key press), the flight time (the time between the key release of the previous key and before the key press of the next key), etc. With the mass adoption of smartphone, many additional non-timing features (e.g. finger touching area) are also included in the keystroke dynamics analysis.

1.2 Objective

To identify the effective authentication factors using touchscreen smartphones with random numeric keypad.

1.3 Scope of the research

This research selectively focuses on the study on the effective identification of a combination of factors obtained from the smartphones with random numeric input. Due to the cost and time limitation, the experiment was designed for smartphones with android operating system (OS) and distributed via the Google Play Store.

Furthermore, the experiment is designed for any smartphones with 5-inch and above screen with minimum android OS version 5 that can produce finger touching area value at each touch.

1.4 Expected Outcomes

The combination of factors obtained from the random numeric keypad that has high effectiveness in the identification process can:

- Be applied in the existing PIN-only authentication system such as mobile banking which will help to strengthen the system
- Prevent shoulder surfing attacks
- Prevent smudge attacks

1.5 Definition

Button / Btn	: The button that contains a number/text displayed on the smartphone.
Dwell time / DT	: The time of a single press of a button i.e. starts when the finger touches the button/screen and stops when finger is off the button/screen at a single position.
Finger	: The number of finger(s) used when the tester inputs the numbers.
Finger touching area / area	: The area on the screen that is touched by a finger. In some studies, it is referred to as finger size and is stated as such in the comparison tables.

Flight time / FT	: Time between when the finger leaves the first button and before the finger touches the second button.
Gender	: Gender of the tester in the research.
Smartphone	: A touchscreen phone device.
Tester	: The person who volunteers to participate in this research by inputting the pre-defined numbers on his/her smartphone.
Time	: The time measured are in milliseconds.
User	: The person who uses the application or program.

1.6 Thesis Structure

The remaining chapters consisted of related works that briefly describe the previous studies (Chapter 2), the research methodology that details the methods (Chapter 3) and the results of the research (Chapter 4). Chapter 5 is the discussion and conclusion section and followed by the references and appendix that are listed at the end of the paper.

CHAPTER 2 LITERATURE REVIEW / RELATED WORKS

This Chapter discusses the related works to authentication and biometric methods. The Authentication Section explores papers that are not specific to biometric authentication while the Biometric Methods Section explores papers that are on keystroke dynamics of numeric input and randomized numeric input system.

2.1 Authentication

2.1.1 PINs selection

In regard to PINs selection, it is found that a significant number of users still used easily-guessed numbers. The 2012 study by Bonneau et al. (J. Bonneau, 2012) indicated 23% of the survey respondents used either the year or a combination of month/date/year, 9% used a sequence of number according to position of the numbers on the numeric keypad and 5% used repeated numbers or easily guessed number sequence. Despite 63% of the survey respondents used random numbers, some of these numbers were the PINs given by current or previous banks. Note that the survey was conducted to explore how the users chose their 4-digit PINs involving 805 respondents.

2.1.2 Fingerprint

The use of fingerprint in authentication system has been widely adopted by the public due to its ease of use, accuracy and the availability of fingerprint sensors in the smartphones. Nonetheless, the study conducted by Roy et al. in 2017 (A. Roy, 2017), employed the use of a synthetic fingerprint consisting of full/partial fingerprint that match one or more of fingerprint templates from the optical and capacitive datasets. The results of the study revealed that there was 65.2% attack success when using optical datasets and 26.46% attack success when using capacitive datasets. The study mentioned that partial fingerprints of multiple fingers further increase the attack success.

2.1.3 Feature Selection

The main goal of feature selection is to reduce computation time by using optimal combination of features that results in high accuracy. Kaur et. al (Rajinder Kaur, 2016) studied the various feature selection methods used for the intrusion detection systems to see the effects of the features on the accuracy of the classifiers, to reduce computation time by minimizing the numbers of features used in the analysis. The study's initial number of attributes were 41. The analysis was performed using Bayes Net and Naïve Bayes classifiers with 10-fold cross validation. 9 feature selection methods were used. The results of the study indicated that applying CfsSubsetEval (CFS) and Filtered subset evaluator to the datasets can minimize the time taken for training while using less features. CFS, Correlation-based Feature Subset Selection, selects the subsets of features with low intercorrelation that are highly correlated with the class.

2.2 Biometrics methods

This section discusses the related works in regard to keystroke dynamics and random numeric input. Keystroke dynamics have been extensively studied since the late 20th century and is part of the behavioral biometrics that is still studied until today although the rise of physical biometrics such as fingerprint, iris, face have overshadowed the keystroke dynamics study for the past decades.

In 2010, Maxion and Killourhy (Maxion, 2010) carried out an experiment to find out whether the typing rhythm of a single finger can be used in identification. The study involved collecting data from 28 subjects typing the same 10-digit number (4121937761) for 200 correct repetitions each (four sessions of 50 repetitions each on four alternating days) using only a single index finger. The device used in the study is the number-pad (numpad) portion of a keyboard (located at the right end of most full-sized keyboards). Same passcode was used throughout the experiment to allow control over unanticipated biases and so that data from a user can be used as imposter for other users as part of the validation process. The experiment indicated from nonlinear regression analysis that full practice (in typing the numbers) is achieved after 80-100 repetitions. Random forest classifier was used to analyze the hold-time of a single key, press-press latency and release-press latency features for the entire 200-repetition data set and the results achieved were hit rate of 99.54%, miss rate of 0.46%, EER of 8.6%.

Bakelman, et al. (Bakelman, 2013) from Pace University, in 2013, conducted experiments involving passwords and numeric input using “Pace Classifier”. Pace Classifier refers to the Pace University classification procedure that transforms a multi-class problem into a two-class problem based on vector-difference. They used CMU dataset of 51 subjects containing time-related features for passwords experiments with 31 features and 75 features. EER for the experiments were both 8.7%. As for the study involving numeric input, 30 subjects were asked to input 10-digit numbers (9141937761) over four days with no more than 60 samples per each subject per day. Using 20 samples per subject from the 30 subjects, EER were 10.5% when 31 features were used and 6.1% with 44 features.

Trojahn et al. (M. Trojahn, 2013) did a study to determine whether several time differences can be used in keystroke authentication. The experiment was done using smartphones and included non-timing features such as pressure and size. 152 subjects were asked to enter a predefined 17-digit passphrase for 10 times (only correctly typed data were accepted). From the study the combinations of buttons press and different n-graph (digraph and trigraph) for features analysis yielded the best result of FAR of 4.19% and FRR of 4.59% using K-Means classifier. EER values were not stated in the paper.

Bours and Masoudian (Bours, 2014) studied keystroke dynamics of non-fixed 6-digit numeric inputs in 2014. Out of the 30 subjects involved in the study, 11 used the number keypad portion of the keyboard and 19 used the number row above the letters on the keyboard to type the given 150 random numbers. The first 75 random numbers were common for all subjects while the other 75 were personal. The study also used duration and latencies features, creating 7 templates consisting of varying number of samples per user and the type of input. Applying Adapted Scaled Manhattan Distance (ASMD) and Adapted Scale Euclidean Distance (ASED), EER for the experiments were 29.5%-30.9% and 29.2%-30.7% respectively.

In another study in 2014, Zheng et al. (Zheng, 2014) investigated whether four features obtained from smartphones (acceleration, pressure, size and time) could be used for the identification. The study used five different PINs with three 4-digit PINs (3244, 1111, 5555) and two 8-digit PINs (12597384, 12598416), collecting error-free data from 80 subjects with each subject inputting each PINs for 25 times. One-class learning process was used obtaining EER of 3.65% (for 3244), 6.96% (for 1111), 7.34% (5555), 4.55% (for 12597384), 4.45% (12598416). Some of the conclusions drawn from the results of the study were i) increased numbers of features in training gives higher statistical significance, ii) PIN number with high repetition reduces the difference of tapping behavior between the users, iii) accuracy of the results remain the same for all five PINs after 20 users' actions, implying diminishing gain with more users.

Jain et al. (L. Jain, 2014) did a comparison study between smartphones and the hardware keyboard in regards to the degree of keystroke performance in 2014. The paper did not state which part of the numeric input of the hardware keyboard was used. Nonetheless, since the research followed the experiments in previous studies (Bakelman, 2013; Maxion, 2010) , we assumed that the numpad portion of the keyboard

was used in the comparison study. 30 subjects were asked to input 10-digit numbers (9141937761) on both the soft keyboard on smartphone and hardware keyboard.
The paper stated that the data were collected “over several days with 15-30 samples collected per subject per day”. As such, it is not clear how many repetitions the user did as the number of days was not clearly stated. The features were collectively designed into three sets i.e. i) timing features of hardware keyboard and smartphone, ii) non-timing touchscreen features (finger pressure, x coordinate and y coordinates at each press and release event) and iii) timing features and non-timing touchscreen features (all smartphone features). EER results were 10.5% for the timing features for both hardware and smartphone, 3.5% for non-timing smartphone data and 2.8% for all smartphone features.

In 2015, Yang et al. (Yang, 2015) designed a “TapLock” password system which is a combination of PINs and tap label (user-defined tab area which is either big or small) as a screen unlock tool. 30 subjects were involved in the study and during the password input phase, the users received vibration feedbacks during big finger tap event. The subjects were told to press 0-9 buttons with their thumbs. The thumb-size were analyzed using k-Nearest Neighbor Classification that assigned the thumb-size with either big or small label. The results of the recognition of small finger taps was 98% detection rate and 88% detection rate for big finger taps. The study also launched shoulder-surfing attack scenario where 10 “attackers” stood 0.3m from a user who was inputting the PINs. From the results of such attack scenario, the study reported that it was very easy to guess the input PINs but somewhat difficult to guess the tap label with 30% failed to guess the big/small label for 4-digit PINs and 90% fail to guess the big/small label for 8-digit PINs.

The 2016 research by Kiruthika, K. (Kiruthika, 2016) proposed “SteganoPIN” method for PIN-based authentication to counteract shoulder surfing attacks. SteganoPIN method, deployed via android application, comprised of two independent systems, a response keypad (a numeric keypad with in regular layout and size) and a challenge keypad (a small independent numeric keypad with random layout that only appeared when the user “cupped” or covered the keypad in a “grip circularly closed to form a p-shape and disappeared immediately once the cupped hand was removed). First, a user had to “locate a long-term PIN in regular layout and subsequently maps the key locations onto the challenge keypad for OTP derivation”. Next, the user entered the OTP on the on the response keypad. The study concluded that the method is resilience against “camera-based shoulder-surfing attacks over multiple authentication sessions if a user properly used the system”.

Singh and his colleagues (B. S. Saini, 2017), in 2017, did a study to determine the best possible numeric input for authentication using keystroke dynamics. Four 8-digit numbers were used i) 11223344, ii) 51595159, iii) 70852641 and iv) 15963708. 30 subjects participated in the experiment with each subject typing each numbers 20 times using only the numpad of the keyboard. The features used are hold time (or dwell time), press-press time, press-release time, release-release time and release-press time. Random forest and Naïve Bayes classifiers were used to analyze the data. Using the hold time features only, the best results were from random forest classifier for the “70852641” with FAR of 3.9% and FRR of 53.5%. The result suggested that the random number sequence produced lower FAR and FRR than number with some patterns in them. When both the hold time and latencies were used, the best results were also from random forest classifier for the same number sequence with FAR of 2.7% and FRR of 35.9%. EER values were not stated in the paper.

In 2018, Liu et al. (Liu, 2018) proposed a user-independent inter-keystroke timing attacks on PINs, assuming that the victim used one finger to enter the whole PIN and that the attacker knew the layout of the keyboard. Initially, a malicious user builds a timing dictionary that include all possible PINs and their corresponding timing sequences (derived from the study’s cognitive model. Then the victim’s PIN timing sequence is obtained via some side-channels to compare the cosine similarity between the victim's timing sequence and each entry in the dictionary for similar values. Using the ranked list of candidate PINs, the malicious user may hack into the victim's account using the PINs successively from the ranked list.

In the study, the researchers defined the strength of 6-digit PINs by five levels with level 1 the easiest to replicate and level 5 the most difficult. The PIN strength was based on the directional density of the inter-keystroke timing sequences in the timing dictionary. 55 users participated and were compensated for their time. The experiment involved training and testing sessions on the numpad portion of a keyboard. The study found that typing the PINs for five times was sufficient for a user to type the PINs fluently.

In the training session, five users were assigned to enter three 6-digit PINs randomized from the whole 6-digit PIN space and to type each PIN 15 times correctly after some practice. 50 PINs with 10 randomized PINs from each five PIN strength levels were used for the testing session. 50 users were to type 25 PINs (with five PINs chosen randomly from the PINs in each strength level) and to type each PIN for 15 times after 5 practice rounds. Note that the selection of the other 20 PINs was not explained in the paper. With known digits attacks, the success rate of guessing the correct PIN at level 1 within three attempts are 14.2% (one digit known), 23.3% (two digits known) and 34.9% (three digits known). The study inferred that the risk from attacks is higher with shorter PINs. The study also proposed a new keyboard layout with the numbers forming a circle around the "enter" key with all 10 digits evenly distributed. A user had to press enter after each time a number was pressed and to press enter twice to submit the PIN after completion.

The researchers believe that this is the first work to propose an authentication system based on finger touching area and keystroke dynamics from numeric keypad with random numbers. Previous studies mostly used numeric keypad in its regular layout using the numeric keypad portion of the keyboard or virtual numeric keypad on smartphone. The study in (Bours, 2014) involved randomized OTP but was done via regular numeric keypad as previously mentioned. Meanwhile, the study in (Kiruthika, 2016) proposed a method that included a randomized numeric input to generate OTP but did not study keystroke dynamics of the users. On the other hand, the new keyboard layout proposed in (Liu, 2018) study may confuse some users due to frequent "enter" input.

Note that randomized numeric virtual keypad is also implemented by some Thai banks in their internet banking system for a user to input OTP for financial transactions. However, a user has to input the OTP using a mouse which has a lower degree of keystroke performance (L. Jain, 2014).

Table 1. Brief prominent features in past researches mentioned in related works

Research by	***Purpose***	***Fixed # / Random #***	***Data collection device***	***Features used***
Maxion and Killourhy (Maxion, 2010)	Keystroke dynamics study of a single index finger	Fixed 10-digit #	Keyboards	• Hold time of single key, • Press-press latency, • Release-press latency
Bakelman, et al. (Bakelman, 2013)	Keystroke dynamics study	Fixed 10-digit #	Keyboards	• 31-41 time related features
Trojahn et al. (M. Trojahn, 2013)	Keystroke dynamics study	Fixed 17-digit #	Smartphones	• Timing features • Pressure • Size
Bours and Masoudian (Bours, 2014)	Keystroke dynamics study	Random 6-digit # (OTP)	Keyboards	• Timing features
Zheng et al. (Zheng, 2014)	Keystroke dynamics study	Fixed 4-digit and 8-digit #	Smartphones	• Acceleration • Pressure • Size • Time

Table 1. Brief prominent features in past researches mentioned in related works

Research by	***Purpose***	***Fixed # / Random #***	***Data collection device***	***Features used***
Jain et al. (L. Jain, 2014)	Keystroke dynamics study comparison between phone and keyboard	Fixed 10-digit #	Smartphones and keyboards	• Timing features • Non-timing features (pressure, coordinates)
Yang et al. (Yang, 2015)	Proposed new “TapLock” system – combination of PINs and tap label a screen unlock tool	Fixed #	Smartphones	• Finger size
Kiruthika, K. (Kiruthika, 2016)	Proposed “SteganoPIN” method for authentication	Randomized # (OTP) derived from fixed #	Smartphones	• NA
Singh et al. (B. S. Saini, 2017)	Keystroke dynamics study to find the best numeric input for authentication	Fixed 8-digit #	Keyboards	• Hold time • Press-press time • Press-release time • Release-release time • Release-press time

Table 1. Brief prominent features in past researches mentioned in related works

Research by	***Purpose***	***Fixed # / Random #***	***Data collection device***	***Features used***
Liu et al. (Liu, 2018)	Proposed user-independent inter-keystroke timing attacks and a new numeric keyboard design	Random 6-digit #	Keyboards	• Timing features
The preliminary study	Keystroke dynamics study using random numeric keypad	Fixed 10-digit #	Smartphones	• Hold time • Release-press latency • Finger size • Gender
The experiment	Keystroke dynamics study using random numeric keypad	Fixed 10-digit #	Smartphones	• Hold time • Release-press latency • Finger size • Gender • Finger # (number of finger used in inputting the numeric input, either 1 or 2)

The Table 1 presents a brief description of previous studies mentioned. Most of the past works that studied keystroke dynamics did not consider the risks from shoulder surfing and smudge attack. Meanwhile the researches that did, mostly propose new authentication methods that are different from the current numeric input system. As such, this research focuses on determining the effective authentication factors using random numeric input. These effective authentication factors can be used to help strengthened the authentication system that can also help to prevent shoulder surfing and smudge attacks.

CHAPTER 3 RESEARCH METHODOLOGY

This section comprises of data collection, the features and data preprocessing, and the classification sections for the preliminary study and the experiment. This section also includes the results from the preliminary study.

From other research papers, the number of subjects vary from 10 to 152. So preliminary study was conducted to determine whether 30 subjects were sufficient for the experiment. The subjects were chosen via convenience sampling and snowball sampling.

The proposed method involves different subjects inputting a fixed 10-digit numbers via android application (NumpadKD) that displays random numbers during each input. The fixed 10-digit numbers used in this study is "9468553594" and was randomly generated from https://passwordsgenerator.net.

3.1 The Preliminary Study

3.1.1 Application Design

The section discusses the screen and the function designs of the applications. In the preliminary study, the tester was asked to input the 10-digit numbers indicated at the top of the screen using the random numeric keypad 10 times continuously.

3.1.1.1 Screen design

The android application is designed to work only in portrait orientation and is designed for smartphones with at least 5-inch screen. This is so that the size and gaps between the buttons will be the same across all devices. The size of a button is defined at 11mm in diameter each, the column-gap of 4mm and row-gap of 3mm between the buttons. Note that the research design did not follow google material design convention to aesthetically fit all screen sizes.

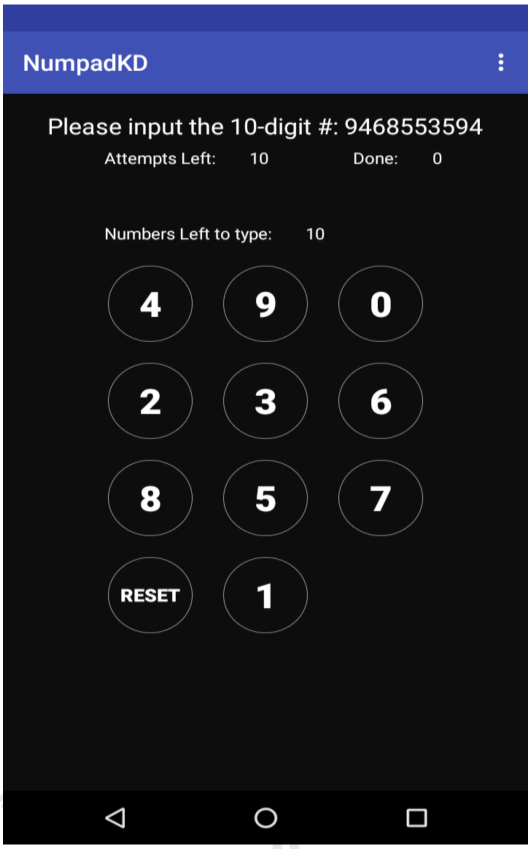


Figure 2. The interface of the application (start screen)

The application is designed with a black background to lessen eye-constraint that may result from the white one. In addition to the button layout as explained above, the buttons are in round shape so as to resemble the typical mobile banking log-in. Also, the relative location of the buttons containing the numbers (0-9) are the same as the numeric keypad (numpad) used in the current mobile banking application.

3.1.1.2 Functions design

The application was designed accordingly to support the test. The application contains a text view to display the number input and three counters – i) a counter to indicate the number of attempts left in the session, ii) a counter to indicate the number of correct instances of the numeric input and ii) a counter to indicate the number of numeric inputs left to be typed in a single instance.

During the experiment, when a tester input incorrect numbers, the tester can use the "reset" button to start again. A pop-up message was triggered upon incorrect 10-digit number input, reminding the tester to use the reset button. The "done" button only appears on the screen when the tester correctly inputs the 10-digit numbers. Touching the "done" button shuffles the numbers to be used in the next round.

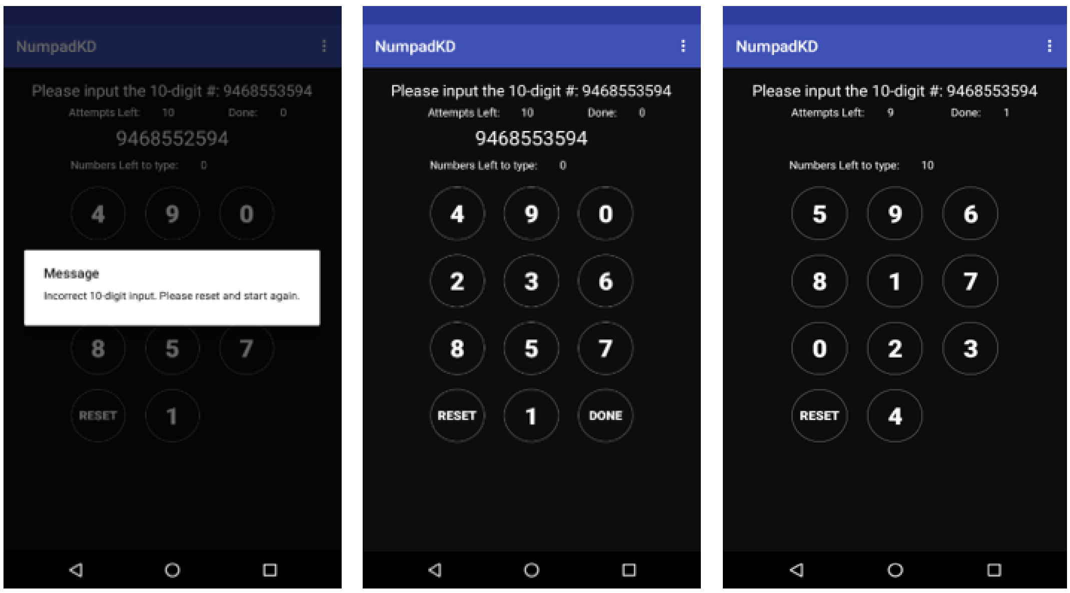


Figure 3. Functions included in the application

(From Left: Pop-up message triggered upon incorrect 10-digit number input, appearance of "DONE" button upon correct 10-digit number input and screen after the "DONE" button is pressed)

Both timing and non-timing features are collected via the android application using the android library MotionEvent ("Android documentation,"). Other than the timing calculation to obtain the flight times and dwell times, only the values from event.getSize() method (the area that is “touched” on the screen at each press) in MotionEvent library is used in the analysis. This is to allow all android devices with screen size of 5 inches and above to be used in the study. This is because not all android devices have pressure sensitivity and the screen sizes of the devices may be slightly different.

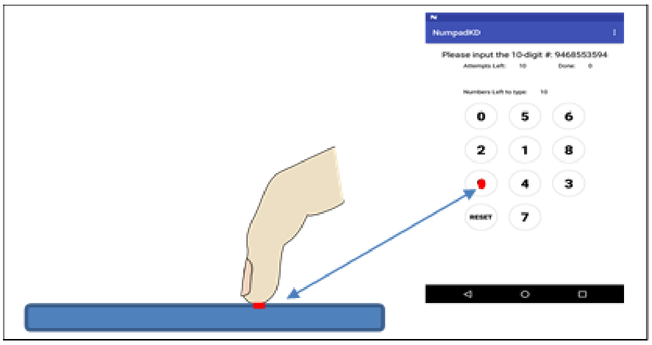


Figure 4. Image of a finger touching area at each press of a button

The timing data captured by the application are indicated in the Figure 3. The data obtained by the application are stored in the phone internal storage to be sent to the researcher via email for further pre-processing to be used in the analysis.

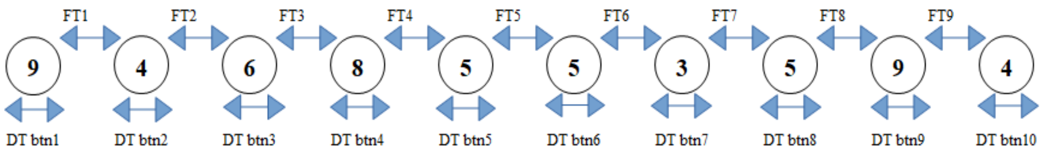


Figure 5. Timing data obtained from the application per one correct input of a subject.

3.1.2 Data Collection

In the preliminary study, the gender of the subjects was collected before the start of the experiment. The subjects consisted of 9 males and 21 females with age ranges from 20 to 60 years old. They were added as alpha testers which allowed them to download the yet-to-release application on their android smartphones via Google Play Store.

Each subject was asked to input the 10-digit number, 10 times continuously. This is so that each subject resembles someone who is familiar with the usage of the numpad with random numbers to input the 10-digit numbers. The total time taken for 10 correct attempts for each subject range from 1.9 to 5.2 minutes, discounting incorrect attempts.

3.1.3 Features and data pre-processing

The data from plain text files from each subject were processed and converted into compatible format for the WEKA software. A total of 32 features were used in the analysis. The features used for each subject were:

- Dwell times of each button pressed and total dwell time (11 features)

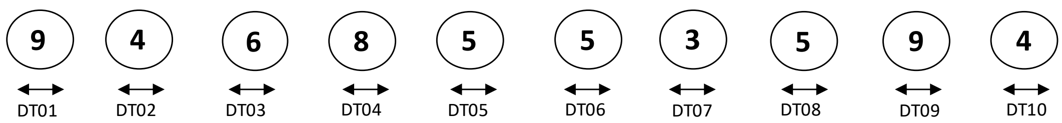


Figure 6. Dwell times

- Flight times between the release-press of the buttons and total flight time (10 features)

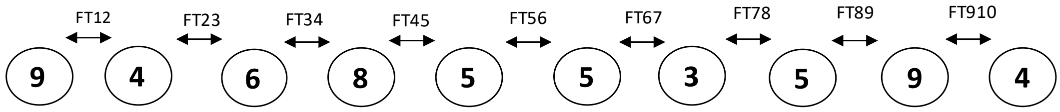


Figure 7. Flight times

- Finger touching area of each button (10 features)

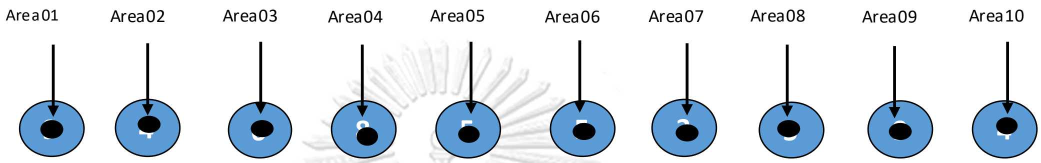


Figure 8. Finger touching areas

- Gender of the subjects (1 feature)

3.1.4 Classification

Random forest classifier is used in the study as it deals with multi-factor classification and also random forest classifier is more effective with random numbers (B. S. Saini, 2017). The study deals with multi-class problem as there are 30 subjects. Given the biometrics authentication is a multiple binary classification problem, MultiClassClassifier implementing 1-against-all method using random forest classifier with 10-fold cross validation was used. At each fold of the 10-fold cross validation, the dataset is divided into 10 equal parts with 9 parts as the training set and 1 part as the testing set. The process of dividing, training, testing was done 10 times (10-fold) and the mean results were obtained.

3.1.5 Results and analysis

From the preliminary study, the weighted results obtained when random forest classifier was used were true positive rate of 80.7%, false positive rate of 0.7%, precision of 81.3% and recall of 80.7% as per Table 2.

Table 2. Brief comparison of results from 3 classifiers in the preliminary study

Classifiers	TP rate	FP rate	Precision	Recall
Random Forest	**0.807**	**0.007**	**0.813**	**0.807**
J48	0.417	0.020	0.498	0.417
Naïve Bayes	0.710	0.010	0.744	0.710

The formula for precision and recall are as follows:

$$Precision = TP / (TP + FP) \quad (1)$$

$$Recall = TP / (TP + FN) \quad (2)$$

where TP is true positive, FP is false positive and FN is false negative.

In various studies, the values that were often reported and compare were the equal error rate (EER). To obtain equal error rate (EER), the following formula is applied:

$$EER = (FPR + FRR) / 2 \quad (3)$$

$$FRR = FNR = FN/(FN + TP) = 1 – TPR \quad (4)$$

Where FPR is false positive rate, FRR is false rejection rate, FNR is false negative rate and TPR is true positive rate. Applying (3), EER is 10%.

The results from the random forest classification indicates moderate effectiveness of the features used in the preliminary study as part of the identification process.

The study was primarily designed to obtain keystroke dynamics from 10-digit numbers. However, the question still remains whether the keystroke dynamics from random numeric input can be applied to the current mobile banking system that require the user to input 6-digit numbers. Since it is possible to obtain 6-digit numbers from the 10-digit numbers. The 10-digit numbers are broken down into 5 sets of 6-digit numbers as indicated in the Figure 9 below.

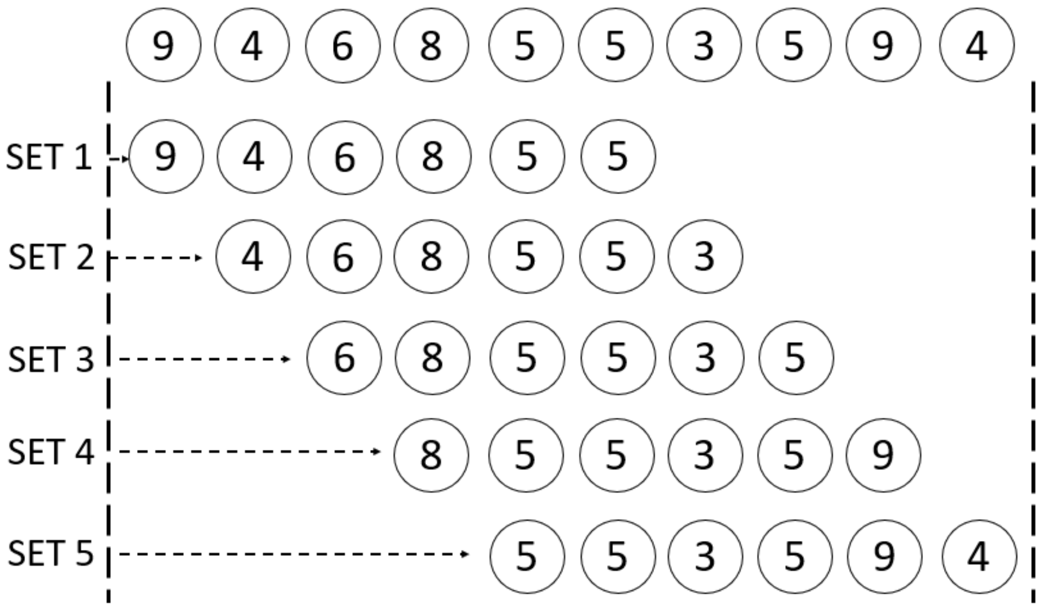


Figure 9. 6-digit combination set obtained from the 10-digit numbers

Applying the same set of features (total flight time, total dwell time, flight times, dwell times, areas and gender), the results for the 5 sets of numbers are stated in the Table 3 below.

Table 3. Preliminary study results for 6-digit numbers

	TP rate	FP rate	Precision	Recall
Preliminary_study_set1_946855	0.757	0.008	0.765	0.757
Preliminary_study_set2_468553	0.757	0.008	0.765	0.757
Preliminary_study_set3_685535	0.767	0.008	0.771	0.767

Table 3. Preliminary study results for 6-digit numbers

	TP rate	FP rate	Precision	Recall
Preliminary_study_set4_855359	0.750	0.009	0.761	0.750
Preliminary_study_set5_553594	0.773	0.008	0.774	0.773

This indicates moderate effectiveness of using areas, dwell times, flight times and gender in the identification process. Nonetheless, it is possible that the accuracy could have been better if more repetitions were collected from the testers as evidenced in some of the previous studies.

3.2 The experiment

Given that preliminary study indicated moderate effectiveness of the combination of features in the identification. In depth experiment was conducted by using the same number of subjects but increased the number of times each subject input the numbers from 10 times to 60 times.

3.2.1 Application Design

The section discusses the screen design and the functions design of the application. In the experiment, each tester was asked to input the numbers 12 times continuously for 5 sessions. Each session was separated by at least 18 hours. The wait between the session is to allow the tester to do his/her everyday tasks and to forget the numbers. This is so that at the next numeric input, the tester resembles a user that may use his/her password in the next day.

The total time taken for a tester to complete the test was at least 4 days. The additional non-timing feature collected in this study is the number of finger(s) used in the experiment aka “finger” (either 1 or 2 fingers, depending on how a tester holds the phone while doing the experiment).

3.1.1.1 Screen design

The application’s screens consisted of:

- Instruction screen which explains the purpose of the research and data handling (collection, usage and storage) and the experiment’s procedure (as no training is provided).

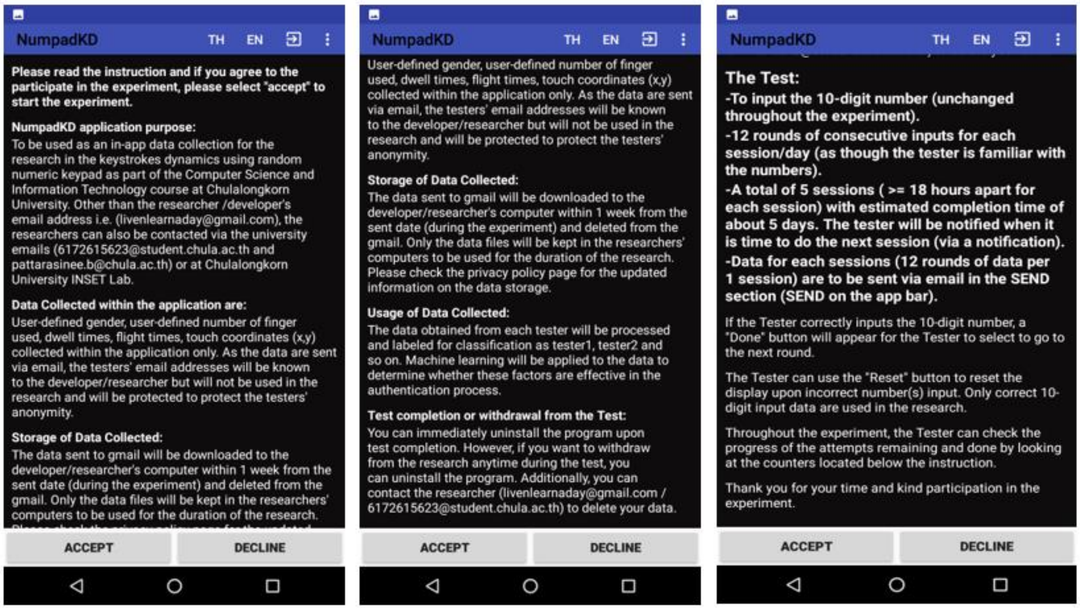


Figure 10. Instruction screen

- Gender and finger data collection screen that collects the user-defined data

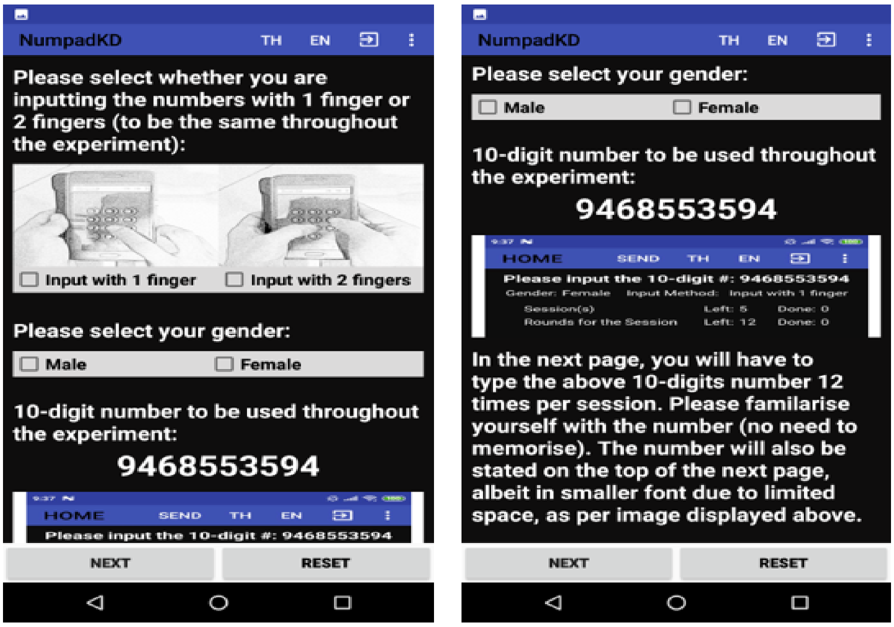


Figure 11. User-defined data collection screen

- Main screen is where the numbers are displayed for the tester to type

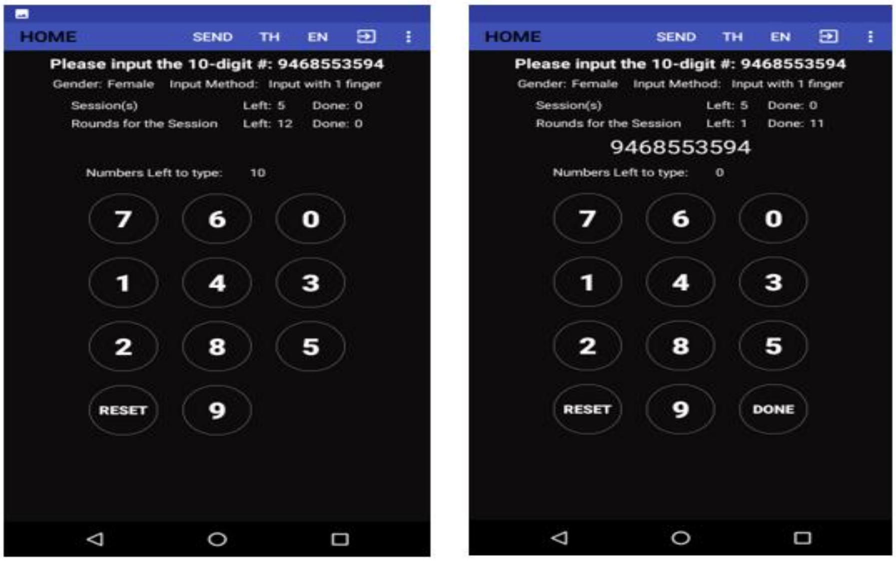


Figure 12. The experiment's main screen

(From left: Before the numbers input, correct 10-digit input in the 12th round in Session 1)

- Send screen where the tester sends the sessions' data files

Figure 13. "SEND" screen

3.1.1.2 Functions design

On the main screen with the numeric input buttons, there are additional texts (gender and input method for number of fingers (finger)) that serve as a reminder, of the options previously chosen, to the tester during each session. The application includes more counters (number of sessions done, number of sessions left, number of rounds done and number of rounds left) to allow the tester to check their progress while doing the experiment. The mechanics of doing the experiment remains the same as in the preliminary study. Similar to the preliminary study, both timing and non-timing features are collected via the android application using the android library MotionEvent ("Android documentation,"). The data obtained by the application are stored in the phone internal storage for each session in separate files.

At the end of each session, after the tester click on the “DONE” button in the final round, there will be a pop-up message to remind the tester to go to the SEND page to send the data file for the session.

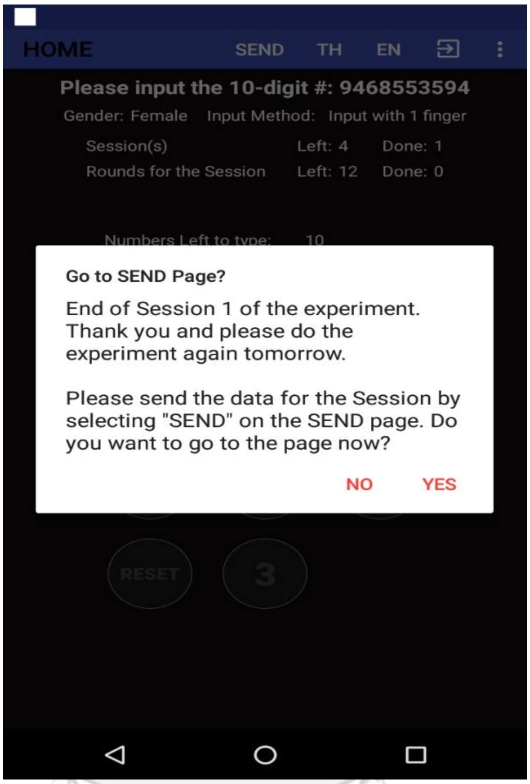


Figure 14. Pop-up message after the tester finished session 1

The tester sends the files to the researcher via email through the “SEND” page in the application.

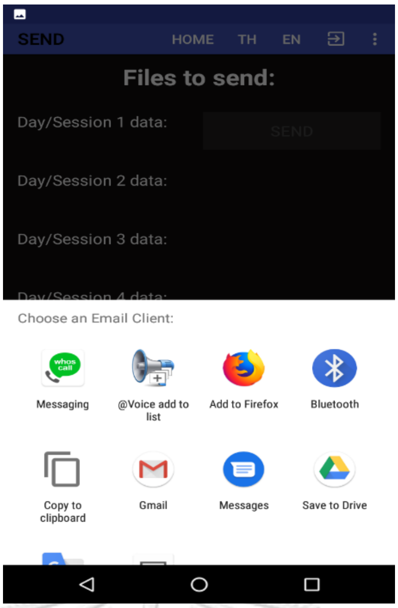


Figure 15. Tester to select email application to send the file for the session

After a session is done, the buttons are greyed out. If the tester clicks on the numeric input, before the time of next input (at least 18 hours apart), there will be a pop-up message telling the tester to wait for next session. Also, the time (in hours) to next session is displayed in the pop-up message.

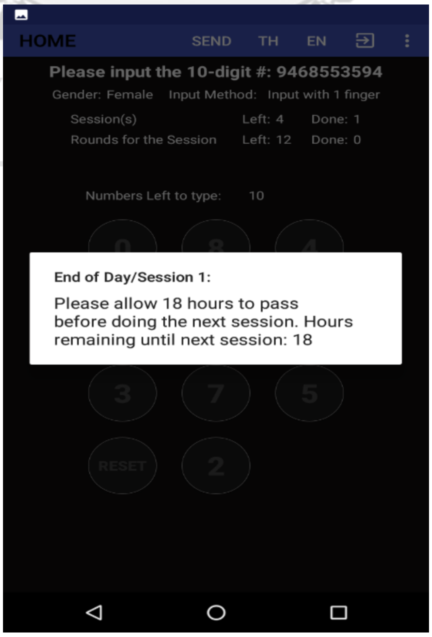


Figure 16. Pop-up message when the tester clicks on the numeric input after completing the first session

When it is time for the next input, a notification will appear to remind the tester to do continue with the experiment.

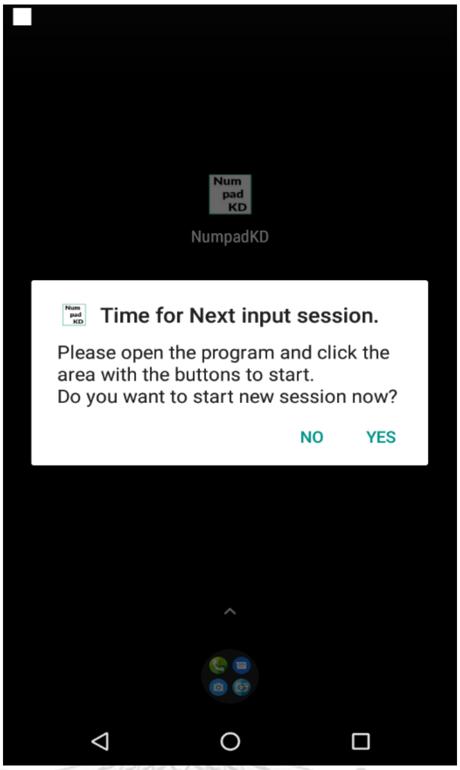


Figure 17. Pop-up message to remind the tester to start the next session

The application is designed in such a way that allows other researchers to use the application to collect the same data using the defined 10-digits (9468553594) as the data are stored in the phone internal storage. The files can be retrieved by the phone owners using the phone's file explorer. There is also option to clear all data which resets the experiment and delete all the files so the experiment can be restarted again if the researcher wants to use the same phone for testing. In the "SEND" page of the application, the tester can also "reset" the "SEND" button for the session to resend the file again. The tester can also send the files manually by using the phone's file explorer to select the files.

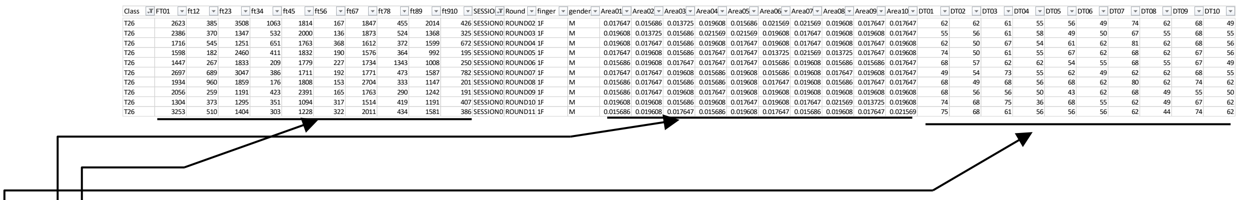
3.1.1.2.1 File format design

The files consisted of a series of Strings that are appended using the Java StringBuilder method. The titles and the values are separated by "#" i.e. title1#value1#title2#value2#...... The data are saves as ".csv" format so as it can be opened in Microsoft excel without having to copy and paste.

```
ft01#2623#SESSION01#ROUND02#BtnPos#Btnr1c2#finger#Input with 1
finger#gender#Male#TouchSize#0.017647#Pressure#1.000000#btnr1c2 dwelltime#62#

ft12#385#SESSION01#ROUND02#BtnPos#Btnr3c2#finger#Input with 1
finger#gender#Male#TouchSize#0.015686#Pressure#1.000000#btnr3c2 dwelltime#62#

ft23#3508#SESSION01#ROUND02#BtnPos#Btnr4c2#finger#Input with 1
finger#gender#Male#TouchSize#0.013725#Pressure#1.000000#btnr4c2 dwelltime#61#

ft34#1063#SESSION01#ROUND02#BtnPos#Btnr3c1#finger#Input with 1
finger#gender#Male#TouchSize#0.019608#Pressure#1.000000#btnr3c1 dwelltime#55#

ft45#1814#SESSION01#ROUND02#BtnPos#Btnr2c2#finger#Input with 1
finger#gender#Male#TouchSize#0.015686#Pressure#1.000000#btnr2c2 dwelltime#56#

ft56#167#SESSION01#ROUND02#BtnPos#Btnr2c2#finger#Input with 1
finger#gender#Male#TouchSize#0.021569#Pressure#1.000000#btnr2c2 dwelltime#49#

ft67#1847#SESSION01#ROUND02#BtnPos#Btnr1c3#finger#Input with 1
finger#gender#Male#TouchSize#0.021569#Pressure#1.000000#btnr1c3 dwelltime#74#

ft78#455#SESSION01#ROUND02#BtnPos#Btnr2c2#finger#Input with 1
finger#gender#Male#TouchSize#0.019608#Pressure#1.000000#btnr2c2 dwelltime#62#

ft89#2014#SESSION01#ROUND02#BtnPos#Btnr1c2#finger#Input with 1
finger#gender#Male#TouchSize#0.017647#Pressure#1.000000#btnr1c2 dwelltime#68#

ft910#426#SESSION01#ROUND02#BtnPos#Btnr3c2#finger#Input with 1
finger#gender#Male#TouchSize#0.017647#Pressure#1.000000#btnr3c2 dwelltime#49#

BTN_DONE#BTN_DONE#SESSION01#BTN_DONE#BTN_DONE#BTN_DONE#finger#Input with 1
finger#gender#Male#emptycell1#emptycell2#emptycell3#emptycell4#emptycell5#emptycell6
```

Figure 18. Raw data file – SESSION01, ROUND02 data of tester 26 (T026)

The data is then processed using the column delimiter in the Microsoft Excel and the final results for a round used in the analysis is as displayed in the Figure 19 below.



Class	FT01	ft12	ft23	ft34	ft45	ft56	ft67	ft78	ft89	ft910
T26	2623	385	3508	1063	1814	167	1847	455	2014	426
T26	2386	370	1347	532	2000	136	1873	524	1368	325
T26	1716	545	1251	651	1763	368	1612	372	1599	672
T26	1598	182	2460	411	1832	190	1576	364	992	195
T26	1447	267	1833	209	1779	227	1734	1343	1008	250
T26	2697	689	3047	386	1711	192	1771	473	1587	782
T26	1934	960	1859	176	1808	153	2704	333	1147	201
T26	2056	259	1191	423	2391	165	1763	290	1242	191
T26	1304	373	1295	351	1094	317	1514	419	1191	407
T26	3253	510	1404	303	1228	322	2011	434	1581	386

Area01	Area02	Area03	Area04	Area05	Area06	Area07	Area08	Area09	Area10
0.017647	0.015686	0.013725	0.019608	0.015686	0.021569	0.021569	0.019608	0.017647	0.017647
0.019608	0.013725	0.015686	0.021569	0.021569	0.019608	0.017647	0.019608	0.019608	0.017647
0.019608	0.017647	0.015686	0.019608	0.017647	0.019608	0.017647	0.019608	0.017647	0.019608
0.017647	0.019608	0.015686	0.017647	0.017647	0.013725	0.021569	0.013725	0.017647	0.019608
0.015686	0.019608	0.017647	0.017647	0.017647	0.015686	0.019608	0.015686	0.015686	0.017647
0.017647	0.017647	0.019608	0.015686	0.019608	0.015686	0.019608	0.017647	0.019608	0.017647
0.015686	0.017647	0.015686	0.015686	0.019608	0.017647	0.019608	0.015686	0.017647	0.017647
0.015686	0.017647	0.019608	0.017647	0.019608	0.019608	0.019608	0.019608	0.019608	0.019608
0.019608	0.019608	0.015686	0.019608	0.017647	0.019608	0.017647	0.021569	0.013725	0.019608
0.015686	0.019608	0.017647	0.015686	0.019608	0.017647	0.015686	0.019608	0.017647	0.021569

DT01	DT02	DT03	DT04	DT05	DT06	DT07	DT08	DT09	DT10
62	62	61	55	56	49	74	62	68	49
55	56	61	58	49	50	67	55	68	55
62	50	67	54	61	62	81	62	68	56
74	50	61	55	67	62	68	62	67	56
68	57	62	62	54	55	68	55	67	49
49	54	73	55	62	49	62	62	68	55
68	49	68	56	68	62	80	62	74	62
68	56	56	50	43	62	68	49	55	50
74	68	75	36	68	55	62	49	67	62
75	68	61	56	56	56	62	44	74	62

Figure 19. A round of pre-processed data to be used in the WEKA software

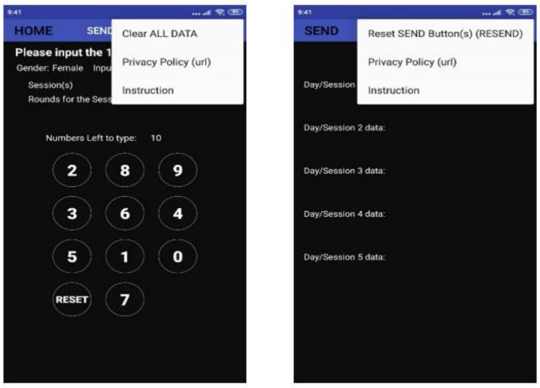


Figure 20. Additional menus the application, designed for reusability.

3.2.2 Data Collection

The application "NumpadKD" was published and released to production phase so that it is available for download to all users who have google account and can download applications via the Google Play Store. The volunteers were obtained via snowball sampling.

The subjects consisted of 10 males and 20 females with age ranges from 20 to 60 years old. 11 subjects use 2 fingers to input the numbers while 19 subjects use 1 finger to input the numbers.

3.2.3 Features and data pre-processing

The data files from each subject were processed and converted into compatible format for the WEKA software. For the experiment, the first and the last rounds in each session (round 1 and round 12) were not included in the analysis. So, for each subject, a total of 50 rounds of data were used in the analysis.

The data used in a round comprises of:

- flight times (9 features):
    - FT12 – flight time between the 1^{st} number and the 2^{nd} number
    - FT23 – flight time between the 2^{nd} number and the 3^{rd} number
    - FT34 – flight time between the 3^{rd} number and the 4^{th} number
    - FT45 – flight time between the 4^{th} number and the 5^{th} number
    - FT56 – flight time between the 5^{th} number and the 6^{th} number
    - FT67 – flight time between the 6^{th} number and the 7^{th} number
    - FT78 – flight time between the 7^{th} number and the 8^{th} number
    - FT89 – flight time between the 8^{th} number and the 9^{th} number
    - FT910 – flight time between the 9^{th} number and the 10^{th} number

- dwell times (10 features):
    - DT1 – dwell time of the 1^{st} number
    - DT2 – dwell time of the 2^{nd} number
    - DT3 – dwell time of the 3^{rd} number
    - DT4 – dwell time of the 4^{th} number
    - DT5 – dwell time of the 5^{th} number
    - DT6 – dwell time of the 6^{th} number
    - DT7 – dwell time of the 7^{th} number
    - DT8 – dwell time of the 8^{th} number
    - DT9 – dwell time of the 9^{th} number
    - DT10 – dwell time of the 10^{th} number

- Finger touching areas (10 features):
    - Area1 – Area registered for the 1^{st} number
    - Area2 – Area registered for the 2^{nd} number
    - Area3 – Area registered for the 3^{rd} number
    - Area4 – Area registered for the 4^{th} number

- Area5 – Area registered for the 5th number
- Area6 – Area registered for the 6th number
- Area7 – Area registered for the 7th number
- Area8 – Area registered for the 8th number
- Area9 – Area registered for the 9th number
- Area10 – Area registered for the 10th number

- Gender (1 feature)
- Finger (1 feature)

For flight times and dwell times, the experiment also considered the total times i.e. total flight times and total dwell times.

Randomized Completed Block Design (RCBD), a statistical method, is used to observe the mean differences between the different groups of factors (flight times, dwell times and areas). A block is essentially a person, whether there are any differences between the features/attributes.

For the flight times features (FT), the main hypothesis is:

H_0 : There is no significant differences among sample means of all groups when the flight times are different.

H_1 : There are at least one significant difference of mean among others when the flight times are different.

Table 4. Randomized Completed Block Design (RCBD) results for Flight times (FT)

Tests of Between-Subjects Effects

Dependent Variable: FT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	8.310E+10[a]	39	2130816533	2287.143	.000
Class	2350214221	29	81041869.68	86.987	.000
Code	5.193E+10	9	5770546891	6193.902	.000
Error	1.394E+10	14961	931649.733		
Total	9.704E+10	15000			

a. R Squared = .856 (Adjusted R Squared = .856)

From Table 4, it can be concluded that there is at least one significant difference of mean among others when the flight times are different because the sig.p-value = 0.00 < 0.05 (alpha) or that H_1 is accepted and H_0 is rejected.

For the dwell times features (DT), the main hypothesis is:

H_0 : There is no significant differences among sample means of all groups when the dwell times are different.

H_1 : There are at least one significant difference of mean among others when the dwell times are different.

Table 5. Randomized Completed Block Design (RCBD) results for dwell times (DT)

Tests of Between-Subjects Effects

Dependent Variable: DT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	1606949103[a]	40	40173727.58	7341.366	.000
Class	22698869.80	29	782719.648	143.035	.000
Code	1060572430	10	106057243.0	19380.951	.000
Error	90073094.68	16460	5472.241		
Total	1697022198	16500			

a. R Squared = .947 (Adjusted R Squared = .947)

From Table 5, it can be concluded that there is at least one significant difference of mean among others when the dwell times are different because the sig.p-value = 0.00 < 0.05 (alpha) or that H_1 is accepted and H_0 is rejected.

For the areas or the finger touching areas features (Area), the main hypothesis is:

H_0 : There is no significant differences among sample means of all groups when the areas are different.

H_1 : There are at least one significant difference of mean among others when the areas are different.

Table 6. Randomized Completed Block Design (RCBD) results for Area (Area)

Tests of Between-Subjects Effects

Dependent Variable: Area

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	83.329[a]	39	2.137	13656.956	.000
Class	50.225	29	1.732	11069.976	.000
Code	.003	9	.000	2.052	.030
Error	2.341	14961	.000		
Total	85.669	15000			

a. R Squared = .973 (Adjusted R Squared = .973)

From Table 6, it can be concluded that there is at least one significant difference of mean among others when the areas are different because the sig.p-value = 0.00 < 0.05 (alpha) or that H_1 is accepted and H_0 is rejected.

From running multiple comparisons using scheffe', we can conclude that the flight times, dwell times and areas features can be used in the experiment. (see appendix Table A1-A3)

To further identify individual group of features and their effectiveness, the experiment separates the data into flight times only group, dwell times only group and areas only group. These data are obtained while the tester performed the test and they vary according to each tester. On the other hand, finger and gender data (user-defined characteristics) are user-defined values and are constant throughout the experiment. After separating the data into their standalone groups, the 3 groups are tested using 4 scenarios.

Scenario 1 (S1): No finger and gender data included in the analysis

Scenario 2 (S2): Finger data is included in the analysis

Scenario 3 (S3): Gender data is included in the analysis

Scenario 4 (S4): Finger and gender data are included in the analysis

The combinations of the features created to test for their effectiveness in identification using the WEKA software are summarized in the Table 7 below.

Table 7. Cases (factor or combination of factors) used to "feed" into the WEKA software

Case	Features	Number of Features
1	Only flight times	10
2	Only flight times, finger	11
3	Only flight times, gender	11
4	Only flight times, finger, gender	12
5	Only dwell times	10
6	Only dwell times, finger	11
7	Only dwell times, gender	11
8	Only dwell times, finger, gender	12
9	Only areas	10
10	Only areas, finger	11
11	Only areas, gender	11
12	Only areas, finger, gender	12
13	Only flight times and dwell times	20
14	Only flight times, dwell times, finger	21
15	Only flight times, dwell times, gender	21
16	Only flight times, dwell times, finger, gender	22
17	Only flight times, areas	20
18	Only flight times, areas, finger	21
19	Only flight times, areas, gender	21
20	Only flight times, areas, finger, gender	22
21	Only dwell times, areas	20
22	Only dwell times, areas, finger	21
23	Only dwell times, areas, gender	21

Table 7. Cases (factor or combination of factors) used to "feed" into the WEKA software

Case	Features	Number of Features
24	Only dwell times, areas, finger, gender	22
25	Flight times, dwell times, areas	29
26	Flight times, dwell times, areas, finger	30
27	Flight times, dwell times, areas, gender	30
28	Flight times, dwell times, areas, finger, gender	31
29	Total DT, total FT, flight times, dwell times, areas, finger, gender	33
30	Total DT, flight times, dwell times, areas, finger, gender	32
31	Total FT, flight times, dwell times, areas, finger, gender	32
32	Total DT, total FT, flight times, dwell times, areas	31
33	Total DT, flight times, dwell times, areas	30
34	Total FT, flight times, dwell times, areas	30

3.2.4 Classification

The classifier used in the experiment (albeit the same one as in the preliminary study) is discussed in more detail in this section.

Identifying individuals from a set of features is a multi-class classification problem. Multi-class classification is usually implemented by comparing a set of features of one class against all the other classes.

Meanwhile, the classifier applied in the experiment is random forest (RF) classifier. Since this research is a classification problem, RF is used as it performed by mean of voting and the final prediction is the prediction result with the most votes. Further, it has also been proven effective for random numbers problems. RF classifier cancels out the biases by using the averages of all predictions and hence does not suffer from the overfitting problem. Note that RF classifier cannot extrapolate and understand time-dependent data.

Using WEKA software, MultiClassClassifier implementing 1-against-all method using random forest classifier with 10-fold cross validation was used in the experiment (the same method used in the preliminary study). 10-fold cross validation is used as it trains the data on multiple train-test splits which give a better indication on performance of the model on unseen data. 10-fold cross-validation is performed on the data as it is a classification problem and not a time-series problem and object order does not matter. Cross-validation also has lower variance than the train-test split method (single hold-out).

CHAPTER 4 RESULTS

In the previous Chapter, the cases are grouped according to their similar features before inputting the data into WEKA Machine learning software to determine the effective factors used in the identification process. This Chapter discusses and compares the results (TP rate, FP rate, Precision and Recall values) obtained from the analysis of the sets of features (see Table 7) using WEKA software.

4.1 Flight times

Table 8. Flight times combinations (case 1 – case 4)

Case	Features	TP Rate	FP Rate	Precision	Recall
1	Only flight times	0.345	0.023	0.331	0.345
2	Only flight times, finger	0.458	0.019	0.452	0.458
3	Only flight times, gender	0.463	0.019	0.463	0.463
4	Only flight times, finger, gender	0.585	0.014	0.587	0.585

The results in Table 8 show that using only flight times is ineffective in the identification process. However, combining flight times with either finger or gender increase its precision by about 10%. Using both finger and gender with flight time increases the effectiveness by about 20%.

4.2 Dwell times

Table 9. Dwell times combinations (case 5 – case 8)

Case	Features	TP Rate	FP Rate	Precision	Recall
5	Only dwell times	0.389	0.021	0.375	0.389
6	Only dwell times, finger	0.473	0.018	0.458	0.473
7	Only dwell times, gender	0.481	0.018	0.477	0.481
8	Only dwell times, finger, gender	0.562	0.015	0.560	0.562

Similar to flight times results, using only dwell times is equally ineffective in identification process as per Table 9. Just like the flight times, the precision and recall increases by 10% - 20% when incorporating finger or gender or both.

4.3 Areas

Table 10. Areas combinations (case 9 – case 12)

Case	Features	TP Rate	FP Rate	Precision	Recall
9	Only areas	0.570	0.015	0.570	0.570
10	Only areas, finger	0.667	0.011	0.666	0.667
11	Only areas, gender	0.682	0.011	0.682	0.682
12	Only areas, finger, gender	0.758	0.008	0.760	0.758

Interestingly, using only areas produces the highest results among the “single group of factors” as seen in Table 10. And just like the results from the flight times group and dwell time group, incorporating finger or gender or both increases the precision and recall by 10%-20%.

4.4 Flight times and dwell times

Table 11. Flight times and dwell times combinations (case 13 – case 16)

Case	Features	TP Rate	FP Rate	Precision	Recall
13	Only flight times and dwell times	0.569	0.015	0.569	0.569
14	Only flight times, dwell times, finger	0.637	0.013	0.636	0.637
15	Only flight times, dwell times, gender	0.654	0.012	0.655	0.654
16	Only flight times, dwell times, finger, gender	0.735	0.009	0.740	0.735

From Table 11, the combination of flight times and dwell times produces better results than their standalone group results. Nonetheless, the effectiveness of this combination is still slightly worse than using only areas. Including the finger or gender factor increases the precision by 7-9% and the precision increases by about 17% when using both finger and gender.

4.5 Flight times and areas

Table 12. Flight times and areas combination (case 17 – case 20)

Case	Features	TP Rate	FP Rate	Precision	Recall
17	Only flight times, areas	0.751	0.009	0.751	0.751
18	Only flight times, areas, finger	0.809	0.007	0.810	0.809
19	Only flight times, areas, gender	0.832	0.006	0.833	0.832
20	Only flight times, areas, finger, gender	0.872	0.004	0.874	0.872

Likewise, the combination of flight times and areas is more effective in the identification than using only areas and only flight times per Table 12. Given area factor is more effective than dwell time, it is not surprising that this combination results in a better precision and recall. The precision increases by 6-8% when using finger or gender and about 12% when both finger and gender are incorporated.

4.6 Dwell times and areas

Table 13. Dwell times and areas combination (case 21 – case 24)

Case	Features	TP Rate	FP Rate	Precision	Recall
21	Only dwell times, areas	0.767	0.008	0.774	0.767
22	Only dwell times, areas, finger	0.823	0.006	0.826	0.823
23	Only dwell times, areas, gender	0.827	0.006	0.829	0.827
24	Only dwell times, areas, finger, gender	0.887	0.004	0.888	0.887

The results from this combination is similar to the flight times and areas combination. Including finger or gender improves the precision by about 6% while using both increases the precision by about 12% as indicated in Table 13.

4.7 Flight times, dwell times, areas

Table 14. Flight times, dwell times and areas combination (case 25 – case 28)

Case	Features	TP Rate	FP Rate	Precision	Recall
25	Flight times, dwell times, areas	0.852	0.005	0.855	0.852
26	Flight times, dwell times, areas, finger	0.883	0.004	0.884	0.883
27	Flight times, dwell times, areas, gender	0.891	0.004	0.896	0.891
28	Flight times, dwell times, areas, finger, gender	0.929	0.002	0.930	0.929

Incorporating all the 3 main feature groups produces the best results per Table 14. Case 28 produces the best results in this combination. It is to be noted that without using finger or gender, the results from the combination of just the 3 main feature groups i.e. case 25 are still inferior to case 20 and case 24.

4.8 Incorporating total flight times and total dwell times

Table 15. Total flight times, total dwell times, flight times, dwell times and areas combination (case 29 – case 34)

Case	Features	TP Rate	FP Rate	Precision	Recall
29	Total DT, total FT, flight times, dwell times, areas, finger, gender	0.921	0.003	0.924	0.921
30	Total DT, flight times, dwell times, areas, finger, gender	0.930	0.002	0.932	0.930
31	Total FT, flight times, dwell times, areas, finger, gender	0.920	0.003	0.923	0.920
32	Total DT, total FT, flight times, dwell times, areas	0.841	0.005	0.842	0.841
33	Total DT, flight times, dwell times, areas	0.845	0.005	0.848	0.845
34	Total FT, flight times, dwell times, areas	0.839	0.006	0.841	0.839

To further investigate whether more factors can result in better accuracy, the total flight times and total dwell times are incorporated into case 28. From the above results in Table 15, it can be inferred that using total flight times and total dwell times does not significantly improve the results, in fact, the results from case 29 and case 31 are slightly inferior to case 28. Also, including user-defined values can help to improve the accuracy by about 8%.

4.9 Testing with Naïve Bayes and J48 using feature sets in case 28 and case 30

In this section, just like the preliminary study, Naïve Bayes and J48 classifiers are used instead of random forest to determine whether the results from random forest classifier are the best ones.

Table 16. Results from 3 classifiers using feature sets from case 28 and case 30.

Classifiers	Case	TP rate	FP rate	Precision	Recall
Random Forest	Case 28	0.929	0.002	0.930	0.929
J48	Case 28	0.725	0.009	0.740	0.725
Naïve Bayes	Case 28	0.807	0.007	0.822	0.807
Random Forest	Case 30	0.930	0.002	0.932	0.930
J48	Case 30	0.735	0.009	0.763	0.735
Naïve Bayes	Case 30	0.793	0.007	0.809	0.793

The results from the Table 16 affirmed that random forest classifier produce the best results among the classifier for case 28 and case 30.

4.10 Using 2 of the most effectiveness combinations aka case 28 and case 30 to test for effectiveness of 6-digit combination obtained from the 10-digit numbers

Continuing from the preliminary study, 5 sets of numbers are applied using the features case 28 and case 30 as in Section 4.7 and section 4.8, the results from case 28 and case 30 are among the best.

Table 17. Applying features used in case 28 and case 30 to the 6-digits sets (case 35 – case 44)

Case	Features	TP Rate	FP Rate	Precision	Recall
35	6D_SET1_ (946855)_case28	0.891	0.004	0.893	0.891
36	6D_SET2_(468553)_case28	0.899	0.003	0.901	0.899
37	6D_SET3_(685535)_case28	0.892	0.004	0.894	0.892
38	6D_SET4_(855359)_case28	0.894	0.004	0.896	0.894
39	6D_SET5_(553594)_case28	0.885	0.004	0.887	0.885
40	6D_SET1_(946855)_case30	0.905	0.003	0.907	0.905
41	6D_SET2_(468553)_case30	0.894	0.004	0.896	0.894
42	6D_SET3_(685535)_case30	0.898	0.004	0.900	0.898
43	6D_SET4_(855359)_case30	0.894	0.004	0.896	0.894
44	6D_SET5_(553594)_case30	0.890	0.004	0.892	0.890

The above results in Table 17 indicate relatively high effectiveness when using the combination of dwell times, flight times, areas, finger and gender for 6-digit numbers. The addition of total dwell times (feature from case 30) only marginally improve the results for case 40 (946855), case 42 (685535), case 44 (553594).

4.11 Comparing the results of the experiment with the preliminary study

In the experiment, each tester was asked to input 12 rounds of data for 5 sessions instead of just 10 rounds of data in 1 session. Further, since each session is designed to be separated at least 18 hours, the total time taken for 1 tester to complete the whole experiment is at least 4 days compare to less than 10min for the preliminary study. So, in this section, the results from the experiment are compared with the Preliminary study so as to evaluate whether the increased effort yield significantly better results.

Table 18. Comparison between the experiment and the preliminary study

Features	Case	TP Rate	FP Rate	Precision	Recall
Total flight times, total dwell times, flight times, dwell times, areas, gender	Preliminary Study	0.807	0.007	0.813	0.807
	Case 45	0.888	0.004	0.891	0.888
Flight times, dwell times, areas, gender (excludes total flight time and total dwell time)	Preliminary Study	0.777	0.008	0.776	0.777
	Case 46	0.891	0.004	0.896	0.891
Total DT, flight times, dwell times, areas, gender (excludes total flight time)	Preliminary Study	0.817	0.006	0.826	0.817
	Case 47	0.893	0.004	0.896	0.893

From Table 18, it can be inferred that increased data from increased repetition (from 10 to 50 rounds of data) can improve the results from 8-12%.

CHAPTER 5 DISCUSSION AND CONCLUSION

5.1 Discussion

The experiment produces more accurate result than the preliminary study. Table 19 shows the major differences between the experiment and the preliminary study.

Table 19. Differences between the experiment and the preliminary study

	The experiment	Preliminary Study
Number of rounds / instances of data used in analysis for each tester	50	10
Non-timing features used other than areas	Gender, finger	Gender

The experiment reveals that timing features only are not effective in the identification process when random numeric keypad is used. However, the timing features have been proven effective for the typical numeric keypad. It is likely due to a subject's familiarity with the layout of the keypad and hence creating a certain rhythm that is repeatable.

In the experiment, the results indicate that including 1 user-defined value (finger / gender) can improve the results by about 10% and including 2 user-defined values (finger and gender) can improve the results by 20%. However, it is to be noted that there is unequal sample size for each of the user-defined values and this research did not investigate how such occurrences impact the overall accuracy.

Pairing the 2 groups of factors only indicates that timing pairs (flight times and dwell times) are only fairly effectiveness in the identification process. Meanwhile, pairing the areas with timing factors is more effective. As mentioned above, including the user-defined values help to improve the effectiveness of the pairs.

Unsurprisingly, the combinations that are among the most effective are case 28 (flight times, dwell times, areas, finger, gender) and case 30 (flight times, dwell times, areas), finger, gender and total dwell time) with true positive rate of 92.9% and 93% respectively. However, it is to be noted that the combination with the most features are not necessarily the most effectiveness as per case 29 (flight times, dwell times, areas, total flight times and total dwell times) with true positive rate of 92.1%, although the results are somewhat comparable.

In dealing with the 6-digit number sets, using the most effective combinations as obtained from the experiment improves the effectiveness in identification process by about 15% from the preliminary study. Nonetheless, it remains to be seen whether a different set of numbers can produce the same or similar results using the random numeric keypad.

The Table 20 compares the results from the experiment, the preliminary study and other related works in Chapter 2.

Table 20. Results from related works in Chapter 2 and from the preliminary study and the experiment

Research by	# subjects	Classifier	Features used (T – time related; NT – non-time related)			EER
			T	NT	Note	
Maxion and Killourhy(Maxion, 2010)	28	Random forest	x		Hold time of single key, Press-press latency, Release-press latency	8.6%
Bakelman, et al. (Bakelman, 2013)	30	Pace Classifier	x		31-41 time related features	6.1% -10.5%
Trojahn et al. (M. Trojahn, 2013)	152	K-Means classifier	x	x	Timing features, Pressure, size	*4.39%
Bours and Masoudian (Bours, 2014)	30	Adapted Scaled Manhattan Distance and Adapted Scale Euclidean Distance	x		Timing features	29.2% -30.9%
Zheng et al. (Zheng, 2014)	80	One-class classifier	x	x	Acceleration, Pressure, Size, time	3.65% - 7.34%
Jain et al. (L. Jain, 2014)	30	One-class SVM	x	x	Timing features, Pressure, Coordinates	2.8% - 10.5%
Singh et al. (B. S. Saini, 2017)	30	Random forest and Naïve Bayes	x		Hold time, press-press time, press-release time, release-release time, release-press time	*19.3% -28.7%

Table 20. Results from related works in Chapter 2 and from the preliminary study and the experiment

Research by	# subjects	Classifier	Features used (T – time related; NT – non-time related)			EER
			T	NT	Note	
The preliminary study	30	Random forest	x	x	Hold time, Release-press latency, Finger size, Gender	*10%
The experiment	30	Random forest	x	x	Hold time, Release-press latency, Finger size, Gender, Finger #	*3.6%

*Applying Equation (3)

5.2 Limitation of the experiment

Despite the experiment focuses on applying keystroke dynamics and user-defined values to existing system which seem less complex than proposed new systems [12, 14], some of the research constraints in the experiment are:

- small number of subjects (only 30 subjects),
- limited to smartphones with 5-inch and above screen size,
- applied only to android devices,
- limits to a certain designed interface and the selected features.
- unequal sample size for user-defined values which may affect overall accuracy

As such, further researches can be done by implementing the experiment in other operating system such as iOS to further solidify the usability of random numeric keypad on smartphones as part of identification system and to conduct the experiment using equal population size for user-defined values to determine whether such occurrence affect the overall accuracy of the experiment.

5.3 Conclusion

In course of the experiment, it is revealed that the most effective authentication factors or rather identification factors are a combination of various factors i.e. flight times, dwell times, areas, finger, gender and total dwell time. Timing features alone are not effective in the identification using the random numeric keypad. Areas or finger touching areas are more effective than the timing features. The research presents the possibility of applying a combination of features that include keystroke dynamics obtained from smartphones with random numeric keypad in the identification process.

Keystroke dynamics for identification has potential to penetrate the mass market due to its relative low cost of deployment and less privacy invasive when compared to authentication by fingerprint. It can also help to strengthen the current PIN-only authentication to protect the user's data from cyber-attack. Random numeric keypad can help to prevent smudge and shoulder surfing attacks.

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APPENDIX

Table A1. Result of Randomized Completed Block Design (RCBD) for flight times (FT)

Multiple Comparisons

Dependent Variable: FT

Scheffe

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.	Interval Lower Bound	Interval Upper Bound
1	2	783.024*	61.0459	.000	384.683	1181.365
	3	330.804	61.0459	.446	-67.537	729.145
	4	-91.416	61.0459	1.000	-489.757	306.925
	5	1124.136*	61.0459	.000	725.795	1522.477
	6	101.584	61.0459	1.000	-296.757	499.925
	7	701.756*	61.0459	.000	303.415	1100.097
	8	-813.800*	61.0459	.000	-1212.141	-415.459
	9	364.064	61.0459	.187	-34.277	762.405
	10	9.792	61.0459	1.000	-388.549	408.133
	11	641.612*	61.0459	.000	243.271	1039.953
	12	809.420*	61.0459	.000	411.079	1207.761
	13	-147.576	61.0459	1.000	-545.917	250.765
	14	851.216*	61.0459	.000	452.875	1249.557
	15	240.220	61.0459	.981	-158.121	638.561
	16	715.376*	61.0459	.000	317.035	1113.717
	17	900.348*	61.0459	.000	502.007	1298.689
	18	-53.960	61.0459	1.000	-452.301	344.381
	19	592.888*	61.0459	.000	194.547	991.229
	20	536.644*	61.0459	.000	138.303	934.985
	21	281.912	61.0459	.847	-116.429	680.253
	22	321.344	61.0459	.534	-76.997	719.685
	23	509.552*	61.0459	.000	111.211	907.893
	24	-40.696	61.0459	1.000	-439.037	357.645
	25	728.476*	61.0459	.000	330.135	1126.817
	26	190.460	61.0459	1.000	-207.881	588.801
	27	504.564*	61.0459	.000	106.223	902.905
	28	636.600*	61.0459	.000	238.259	1034.941
	29	385.336	61.0459	.087	-13.005	783.677
	30	495.764*	61.0459	.000	97.423	894.105
2	3	-452.220*	61.0459	.003	-850.561	-53.879
	4	-874.440*	61.0459	.000	-1272.781	-476.099
	5	341.112	61.0459	.355	-57.229	739.453
	6	-681.440*	61.0459	.000	-1079.781	-283.099
	7	-81.268	61.0459	1.000	-479.609	317.073
	8	-1596.824*	61.0459	.000	-1995.165	-1198.483
	9	-418.960*	61.0459	.018	-817.301	-20.619
	10	-773.232*	61.0459	.000	-1171.573	-374.891
	11	-141.412	61.0459	1.000	-539.753	256.929
	12	26.396	61.0459	1.000	-371.945	424.737
	13	-930.600*	61.0459	.000	-1328.941	-532.259
	14	68.192	61.0459	1.000	-330.149	466.533
	15	-542.804*	61.0459	.000	-941.145	-144.463
	16	-67.648	61.0459	1.000	-465.989	330.693
	17	117.324	61.0459	1.000	-281.017	515.665
	18	-836.984*	61.0459	.000	-1235.325	-438.643
	19	-190.136	61.0459	1.000	-588.477	208.205
	20	-246.380	61.0459	.972	-644.721	151.961
	21	-501.112*	61.0459	.000	-899.453	-102.771
	22	-461.680*	61.0459	.001	-860.021	-63.339
	23	-273.472	61.0459	.891	-671.813	124.869
	24	-823.720*	61.0459	.000	-1222.061	-425.379
	25	-54.548	61.0459	1.000	-452.889	343.793
	26	-592.564*	61.0459	.000	-990.905	-194.223
	27	-278.460	61.0459	.866	-676.801	119.881
	28	-146.424	61.0459	1.000	-544.765	251.917
	29	-397.688	61.0459	.051	-796.029	.653
	30	-287.260	61.0459	.814	-685.601	111.081
3	4	-422.220*	61.0459	.015	-820.561	-23.879
	5	793.332*	61.0459	.000	394.991	1191.673
	6	-229.220	61.0459	.991	-627.561	169.121
	7	370.952	61.0459	.148	-27.389	769.293
	8	-1144.604*	61.0459	.000	-1542.945	-746.263
	9	33.260	61.0459	1.000	-365.081	431.601
	10	-321.012	61.0459	.537	-719.353	77.329
	11	310.808	61.0459	.630	-87.533	709.149
	12	478.616*	61.0459	.000	80.275	876.957
	13	-478.380*	61.0459	.000	-876.721	-80.039
	14	520.412*	61.0459	.000	122.071	918.753
	15	-90.584	61.0459	1.000	-488.925	307.757
	16	384.572	61.0459	.089	-13.769	782.913
	17	569.544*	61.0459	.000	171.203	967.885
	18	-384.764	61.0459	.089	-783.105	13.577
	19	262.084	61.0459	.935	-136.257	660.425
	20	205.840	61.0459	.999	-192.501	604.181
	21	-48.892	61.0459	1.000	-447.233	349.449
	22	-9.460	61.0459	1.000	-407.801	388.881
	23	178.748	61.0459	1.000	-219.593	577.089
	24	-371.500	61.0459	.146	-769.841	26.841
	25	397.672	61.0459	.052	-.669	796.013
	26	-140.344	61.0459	1.000	-538.685	257.997
	27	173.760	61.0459	1.000	-224.581	572.101
	28	305.796	61.0459	.673	-92.545	704.137
	29	54.532	61.0459	1.000	-343.809	452.873
	30	164.960	61.0459	1.000	-233.381	563.301
4	5	1215.552*	61.0459	.000	817.211	1613.893
	6	193.000	61.0459	1.000	-205.341	591.341
	7	793.172*	61.0459	.000	394.831	1191.513
	8	-722.384*	61.0459	.000	-1120.725	-324.043
	9	455.480*	61.0459	.002	57.139	853.821
	10	101.208	61.0459	1.000	-297.133	499.549
	11	733.028*	61.0459	.000	334.687	1131.369
	12	900.836*	61.0459	.000	502.495	1299.177
	13	-56.160	61.0459	1.000	-454.501	342.181
	14	942.632*	61.0459	.000	544.291	1340.973
	15	331.636	61.0459	.439	-66.705	729.977
	16	806.792*	61.0459	.000	408.451	1205.133
	17	991.764*	61.0459	.000	593.423	1390.105
	18	37.456	61.0459	1.000	-360.885	435.797
	19	684.304*	61.0459	.000	285.963	1082.645
	20	628.060*	61.0459	.000	229.719	1026.401
	21	373.328	61.0459	.137	-25.013	771.669
	22	412.760*	61.0459	.025	14.419	811.101
	23	600.968*	61.0459	.000	202.627	999.309
	24	50.720	61.0459	1.000	-347.621	449.061
	25	819.892*	61.0459	.000	421.551	1218.233
	26	281.876	61.0459	.847	-116.465	680.217
	27	595.980*	61.0459	.000	197.639	994.321
	28	728.016*	61.0459	.000	329.675	1126.357
	29	476.752*	61.0459	.000	78.411	875.093
	30	587.180*	61.0459	.000	188.839	985.521

Table A1. Result of Randomized Completed Block Design (RCBD) for flight times (FT)

Multiple Comparisons

Dependent Variable: FT

Scheffe

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.	Interval Lower Bound	Interval Upper Bound
5	6	-1022.552*	61.0459	.000	-1420.893	-624.211
	7	-422.380*	61.0459	.015	-820.721	-24.039
	8	-1937.936*	61.0459	.000	-2336.277	-1539.595
	9	-760.072*	61.0459	.000	-1158.413	-361.731
	10	-1114.344*	61.0459	.000	-1512.685	-716.003
	11	-482.524*	61.0459	.000	-880.865	-84.183
	12	-314.716	61.0459	.594	-713.057	83.625
	13	-1271.712*	61.0459	.000	-1670.053	-873.371
	14	-272.920	61.0459	.893	-671.261	125.421
	15	-883.916*	61.0459	.000	-1282.257	-485.575
	16	-408.760*	61.0459	.031	-807.101	-10.419
	17	-223.788	61.0459	.994	-622.129	174.553
	18	-1178.096*	61.0459	.000	-1576.437	-779.755
	19	-531.248*	61.0459	.000	-929.589	-132.907
	20	-587.492*	61.0459	.000	-985.833	-189.151
	21	-842.224*	61.0459	.000	-1240.565	-443.883
	22	-802.792*	61.0459	.000	-1201.133	-404.451
	23	-614.584*	61.0459	.000	-1012.925	-216.243
	24	-1164.832*	61.0459	.000	-1563.173	-766.491
	25	-395.660	61.0459	.056	-794.001	2.681
	26	-933.676*	61.0459	.000	-1332.017	-535.335
	27	-619.572*	61.0459	.000	-1017.913	-221.231
	28	-487.536*	61.0459	.000	-885.877	-89.195
	29	-738.800*	61.0459	.000	-1137.141	-340.459
	30	-628.372*	61.0459	.000	-1026.713	-230.031
6	7	600.172*	61.0459	.000	201.831	998.513
	8	-915.384*	61.0459	.000	-1313.725	-517.043
	9	262.480	61.0459	.934	-135.861	660.821
	10	-91.792	61.0459	1.000	-490.133	306.549
	11	540.028*	61.0459	.000	141.687	938.369
	12	707.836*	61.0459	.000	309.495	1106.177
	13	-249.160	61.0459	.967	-647.501	149.181
	14	749.632*	61.0459	.000	351.291	1147.973
	15	138.636	61.0459	1.000	-259.705	536.977
	16	613.792*	61.0459	.000	215.451	1012.133
	17	798.764*	61.0459	.000	400.423	1197.105
	18	-155.544	61.0459	1.000	-553.885	242.797
	19	491.304*	61.0459	.000	92.963	889.645
	20	435.060*	61.0459	.007	36.719	833.401
	21	180.328	61.0459	1.000	-218.013	578.669
	22	219.760	61.0459	.995	-178.581	618.101
	23	407.968*	61.0459	.032	9.627	806.309
	24	-142.280	61.0459	1.000	-540.621	256.061
	25	626.892*	61.0459	.000	228.551	1025.233
	26	88.876	61.0459	1.000	-309.465	487.217
	27	402.980*	61.0459	.040	4.639	801.321
	28	535.016*	61.0459	.000	136.675	933.357
	29	283.752	61.0459	.836	-114.589	682.093
	30	394.180	61.0459	.060	-4.161	792.521
7	8	-1515.556*	61.0459	.000	-1913.897	-1117.215
	9	-337.692	61.0459	.385	-736.033	60.649
	10	-691.964*	61.0459	.000	-1090.305	-293.623
	11	-60.144	61.0459	1.000	-458.485	338.197
	12	107.664	61.0459	1.000	-290.677	506.005
	13	-849.332*	61.0459	.000	-1247.673	-450.991
	14	149.460	61.0459	1.000	-248.881	547.801
	15	-461.536*	61.0459	.001	-859.877	-63.195
	16	13.620	61.0459	1.000	-384.721	411.961
	17	198.592	61.0459	.999	-199.749	596.933
	18	-755.716*	61.0459	.000	-1154.057	-357.375
	19	-108.868	61.0459	1.000	-507.209	289.473
	20	-165.112	61.0459	1.000	-563.453	233.229
	21	-419.844*	61.0459	.017	-818.185	-21.503
	22	-380.412	61.0459	.105	-778.753	17.929
	23	-192.204	61.0459	1.000	-590.545	206.137
	24	-742.452*	61.0459	.000	-1140.793	-344.111
	25	26.720	61.0459	1.000	-371.621	425.061
	26	-511.296*	61.0459	.000	-909.637	-112.955
	27	-197.192	61.0459	.999	-595.533	201.149
	28	-65.156	61.0459	1.000	-463.497	333.185
	29	-316.420	61.0459	.579	-714.761	81.921
	30	-205.992	61.0459	.999	-604.333	192.349
8	9	1177.864*	61.0459	.000	779.523	1576.205
	10	823.592*	61.0459	.000	425.251	1221.933
	11	1455.412*	61.0459	.000	1057.071	1853.753
	12	1623.220*	61.0459	.000	1224.879	2021.561
	13	666.224*	61.0459	.000	267.883	1064.565
	14	1665.016*	61.0459	.000	1266.675	2063.357
	15	1054.020*	61.0459	.000	655.679	1452.361
	16	1529.176*	61.0459	.000	1130.835	1927.517
	17	1714.148*	61.0459	.000	1315.807	2112.489
	18	759.840*	61.0459	.000	361.499	1158.181
	19	1406.688*	61.0459	.000	1008.347	1805.029
	20	1350.444*	61.0459	.000	952.103	1748.785
	21	1095.712*	61.0459	.000	697.371	1494.053
	22	1135.144*	61.0459	.000	736.803	1533.485
	23	1323.352*	61.0459	.000	925.011	1721.693
	24	773.104*	61.0459	.000	374.763	1171.445
	25	1542.276*	61.0459	.000	1143.935	1940.617
	26	1004.260*	61.0459	.000	605.919	1402.601
	27	1318.364*	61.0459	.000	920.023	1716.705
	28	1450.400*	61.0459	.000	1052.059	1848.741
	29	1199.136*	61.0459	.000	800.795	1597.477
	30	1309.564*	61.0459	.000	911.223	1707.905

Table A1. Result of Randomized Completed Block Design (RCBD) for flight times (FT)

Multiple Comparisons

Dependent Variable: FT

Scheffe

(I) Class		Mean Difference (I-J)	Std. Error	Sig.	Interval Lower Bound	Interval Upper Bound
9	10	-354.272	61.0459	.251	-752.613	44.069
	11	277.548	61.0459	.871	-120.793	675.889
	12	445.356*	61.0459	.004	47.015	843.697
	13	-511.640*	61.0459	.000	-909.981	-113.299
	14	487.152*	61.0459	.000	88.811	885.493
	15	-123.844	61.0459	1.000	-522.185	274.497
	16	351.312	61.0459	.273	-47.029	749.653
	17	536.284*	61.0459	.000	137.943	934.625
	18	-418.024*	61.0459	.019	-816.365	-19.683
	19	228.824	61.0459	.991	-169.517	627.165
	20	172.580	61.0459	1.000	-225.761	570.921
	21	-82.152	61.0459	1.000	-480.493	316.189
	22	-42.720	61.0459	1.000	-441.061	355.621
	23	145.488	61.0459	1.000	-252.853	543.829
	24	-404.760*	61.0459	.037	-803.101	-6.419
	25	364.412	61.0459	.185	-33.929	762.753
	26	-173.604	61.0459	1.000	-571.945	224.737
	27	140.500	61.0459	1.000	-257.841	538.841
	28	272.536	61.0459	.895	-125.805	670.877
	29	21.272	61.0459	1.000	-377.069	419.613
	30	131.700	61.0459	1.000	-266.641	530.041
10	11	631.820*	61.0459	.000	233.479	1030.161
	12	799.628*	61.0459	.000	401.287	1197.969
	13	-157.368	61.0459	1.000	-555.709	240.973
	14	841.424*	61.0459	.000	443.083	1239.765
	15	230.428	61.0459	.990	-167.913	628.769
	16	705.584*	61.0459	.000	307.243	1103.925
	17	890.556*	61.0459	.000	492.215	1288.897
	18	-63.752	61.0459	1.000	-462.093	334.589
	19	583.096*	61.0459	.000	184.755	981.437
	20	526.852*	61.0459	.000	128.511	925.193
	21	272.120	61.0459	.897	-126.221	670.461
	22	311.552	61.0459	.623	-86.789	709.893
	23	499.760*	61.0459	.000	101.419	898.101
	24	-50.488	61.0459	1.000	-448.829	347.853
	25	718.684*	61.0459	.000	320.343	1117.025
	26	180.668	61.0459	1.000	-217.673	579.009
	27	494.772*	61.0459	.000	96.431	893.113
	28	626.808*	61.0459	.000	228.467	1025.149
	29	375.544	61.0459	.126	-22.797	773.885
	30	485.972*	61.0459	.000	87.631	884.313
11	12	167.808	61.0459	1.000	-230.533	566.149
	13	-789.188*	61.0459	.000	-1187.529	-390.847
	14	209.604	61.0459	.998	-188.737	607.945
	15	-401.392*	61.0459	.044	-799.733	-3.051
	16	73.764	61.0459	1.000	-324.577	472.105
	17	258.736	61.0459	.945	-139.605	657.077
	18	-695.572*	61.0459	.000	-1093.913	-297.231
	19	-48.724	61.0459	1.000	-447.065	349.617
	20	-104.968	61.0459	1.000	-503.309	293.373
	21	-359.700	61.0459	.214	-758.041	38.641
	22	-320.268	61.0459	.543	-718.609	78.073
	23	-132.060	61.0459	1.000	-530.401	266.281
	24	-682.308*	61.0459	.000	-1080.649	-283.967
	25	86.864	61.0459	1.000	-311.477	485.205
	26	-451.152*	61.0459	.003	-849.493	-52.811
	27	-137.048	61.0459	1.000	-535.389	261.293
	28	-5.012	61.0459	1.000	-403.353	393.329
	29	-256.276	61.0459	.951	-654.617	142.065
	30	-145.848	61.0459	1.000	-544.189	252.493
12	13	-956.996*	61.0459	.000	-1355.337	-558.655
	14	41.796	61.0459	1.000	-356.545	440.137
	15	-569.200*	61.0459	.000	-967.541	-170.859
	16	-94.044	61.0459	1.000	-492.385	304.297
	17	90.928	61.0459	1.000	-307.413	489.269
	18	-863.380*	61.0459	.000	-1261.721	-465.039
	19	-216.532	61.0459	.997	-614.873	181.809
	20	-272.776	61.0459	.894	-671.117	125.565
	21	-527.508*	61.0459	.000	-925.849	-129.167
	22	-488.076*	61.0459	.000	-886.417	-89.735
	23	-299.868	61.0459	.722	-698.209	98.473
	24	-850.116*	61.0459	.000	-1248.457	-451.775
	25	-80.944	61.0459	1.000	-479.285	317.397
	26	-618.960*	61.0459	.000	-1017.301	-220.619
	27	-304.856	61.0459	.681	-703.197	93.485
	28	-172.820	61.0459	1.000	-571.161	225.521
	29	-424.084*	61.0459	.014	-822.425	-25.743
	30	-313.656	61.0459	.604	-711.997	84.685

Table A1. Result of Randomized Completed Block Design (RCBD) for flight times (FT)

Multiple Comparisons

Dependent Variable: FT

Scheffe

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.	Interval Lower Bound	Interval Upper Bound
13	14	998.792*	61.0459	.000	600.451	1397.133
	15	387.796	61.0459	.079	-10.545	786.137
	16	862.952*	61.0459	.000	464.611	1261.293
	17	1047.924*	61.0459	.000	649.583	1446.265
	18	93.616	61.0459	1.000	-304.725	491.957
	19	740.464*	61.0459	.000	342.123	1138.805
	20	684.220*	61.0459	.000	285.879	1082.561
	21	429.488*	61.0459	.010	31.147	827.829
	22	468.920*	61.0459	.001	70.579	867.261
	23	657.128*	61.0459	.000	258.787	1055.469
	24	106.880	61.0459	1.000	-291.461	505.221
	25	876.052*	61.0459	.000	477.711	1274.393
	26	338.036	61.0459	.382	-60.305	736.377
	27	652.140*	61.0459	.000	253.799	1050.481
	28	784.176*	61.0459	.000	385.835	1182.517
	29	532.912*	61.0459	.000	134.571	931.253
	30	643.340*	61.0459	.000	244.999	1041.681
14	15	-610.996*	61.0459	.000	-1009.337	-212.655
	16	-135.840	61.0459	1.000	-534.181	262.501
	17	49.132	61.0459	1.000	-349.209	447.473
	18	-905.176*	61.0459	.000	-1303.517	-506.835
	19	-258.328	61.0459	.946	-656.669	140.013
	20	-314.572	61.0459	.596	-712.913	83.769
	21	-569.304*	61.0459	.000	-967.645	-170.963
	22	-529.872*	61.0459	.000	-928.213	-131.531
	23	-341.664	61.0459	.350	-740.005	56.677
	24	-891.912*	61.0459	.000	-1290.253	-493.571
	25	-122.740	61.0459	1.000	-521.081	275.601
	26	-660.756*	61.0459	.000	-1059.097	-262.415
	27	-346.652	61.0459	.309	-744.993	51.689
	28	-214.616	61.0459	.997	-612.957	183.725
	29	-465.880*	61.0459	.001	-864.221	-67.539
	30	-355.452	61.0459	.243	-753.793	42.889
15	16	475.156*	61.0459	.001	76.815	873.497
	17	660.128*	61.0459	.000	261.787	1058.469
	18	-294.180	61.0459	.766	-692.521	104.161
	19	352.668	61.0459	.263	-45.673	751.009
	20	296.424	61.0459	.749	-101.917	694.765
	21	41.692	61.0459	1.000	-356.649	440.033
	22	81.124	61.0459	1.000	-317.217	479.465
	23	269.332	61.0459	.909	-129.009	667.673
	24	-280.916	61.0459	.853	-679.257	117.425
	25	488.256*	61.0459	.000	89.915	886.597
	26	-49.760	61.0459	1.000	-448.101	348.581
	27	264.344	61.0459	.927	-133.997	662.685
	28	396.380	61.0459	.055	-1.961	794.721
	29	145.116	61.0459	1.000	-253.225	543.457
	30	255.544	61.0459	.953	-142.797	653.885
16	17	184.972	61.0459	1.000	-213.369	583.313
	18	-769.336*	61.0459	.000	-1167.677	-370.995
	19	-122.488	61.0459	1.000	-520.829	275.853
	20	-178.732	61.0459	1.000	-577.073	219.609
	21	-433.464*	61.0459	.008	-831.805	-35.123
	22	-394.032	61.0459	.060	-792.373	4.309
	23	-205.824	61.0459	.999	-604.165	192.517
	24	-756.072*	61.0459	.000	-1154.413	-357.731
	25	13.100	61.0459	1.000	-385.241	411.441
	26	-524.916*	61.0459	.000	-923.257	-126.575
	27	-210.812	61.0459	.998	-609.153	187.529
	28	-78.776	61.0459	1.000	-477.117	319.565
	29	-330.040	61.0459	.453	-728.381	68.301
	30	-219.612	61.0459	.996	-617.953	178.729
17	18	-954.308*	61.0459	.000	-1352.649	-555.967
	19	-307.460	61.0459	.659	-705.801	90.881
	20	-363.704	61.0459	.189	-762.045	34.637
	21	-618.436*	61.0459	.000	-1016.777	-220.095
	22	-579.004*	61.0459	.000	-977.345	-180.663
	23	-390.796	61.0459	.069	-789.137	7.545
	24	-941.044*	61.0459	.000	-1339.385	-542.703
	25	-171.872	61.0459	1.000	-570.213	226.469
	26	-709.888*	61.0459	.000	-1108.229	-311.547
	27	-395.784	61.0459	.056	-794.125	2.557
	28	-263.748	61.0459	.929	-662.089	134.593
	29	-515.012*	61.0459	.000	-913.353	-116.671
	30	-404.584*	61.0459	.038	-802.925	-6.243
18	19	646.848*	61.0459	.000	248.507	1045.189
	20	590.604*	61.0459	.000	192.263	988.945
	21	335.872	61.0459	.401	-62.469	734.213
	22	375.304	61.0459	.127	-23.037	773.645
	23	563.512*	61.0459	.000	165.171	961.853
	24	13.264	61.0459	1.000	-385.077	411.605
	25	782.436*	61.0459	.000	384.095	1180.777
	26	244.420	61.0459	.975	-153.921	642.761
	27	558.524*	61.0459	.000	160.183	956.865
	28	690.560*	61.0459	.000	292.219	1088.901
	29	439.296*	61.0459	.006	40.955	837.637
	30	549.724*	61.0459	.000	151.383	948.065
19	20	-56.244	61.0459	1.000	-454.585	342.097
	21	-310.976	61.0459	.628	-709.317	87.365
	22	-271.544	61.0459	.899	-669.885	126.797
	23	-83.336	61.0459	1.000	-481.677	315.005
	24	-633.584*	61.0459	.000	-1031.925	-235.243
	25	135.588	61.0459	1.000	-262.753	533.929
	26	-402.428*	61.0459	.041	-800.769	-4.087
	27	-88.324	61.0459	1.000	-486.665	310.017
	28	43.712	61.0459	1.000	-354.629	442.053
	29	-207.552	61.0459	.998	-605.893	190.789
	30	-97.124	61.0459	1.000	-495.465	301.217

Table A1. Result of Randomized Completed Block Design (RCBD) for flight times (FT)

Multiple Comparisons

Dependent Variable: FT

Scheffe

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.	Interval Lower Bound	Interval Upper Bound
20	21	-254.732	61.0459	.955	-653.073	143.609
	22	-215.300	61.0459	.997	-613.641	183.041
	23	-27.092	61.0459	1.000	-425.433	371.249
	24	-577.340*	61.0459	.000	-975.681	-178.999
	25	191.832	61.0459	1.000	-206.509	590.173
	26	-346.184	61.0459	.313	-744.525	52.157
	27	-32.080	61.0459	1.000	-430.421	366.261
	28	99.956	61.0459	1.000	-298.385	498.297
	29	-151.308	61.0459	1.000	-549.649	247.033
	30	-40.880	61.0459	1.000	-439.221	357.461
21	22	39.432	61.0459	1.000	-358.909	437.773
	23	227.640	61.0459	.992	-170.701	625.981
	24	-322.608	61.0459	.522	-720.949	75.733
	25	446.564*	61.0459	.004	48.223	844.905
	26	-91.452	61.0459	1.000	-489.793	306.889
	27	222.652	61.0459	.994	-175.689	620.993
	28	354.688	61.0459	.249	-43.653	753.029
	29	103.424	61.0459	1.000	-294.917	501.765
	30	213.852	61.0459	.997	-184.489	612.193
22	23	188.208	61.0459	1.000	-210.133	586.549
	24	-362.040	61.0459	.199	-760.381	36.301
	25	407.132*	61.0459	.033	8.791	805.473
	26	-130.884	61.0459	1.000	-529.225	267.457
	27	183.220	61.0459	1.000	-215.121	581.561
	28	315.256	61.0459	.590	-83.085	713.597
	29	63.992	61.0459	1.000	-334.349	462.333
	30	174.420	61.0459	1.000	-223.921	572.761
23	24	-550.248*	61.0459	.000	-948.589	-151.907
	25	218.924	61.0459	.996	-179.417	617.265
	26	-319.092	61.0459	.554	-717.433	79.249
	27	-4.988	61.0459	1.000	-403.329	393.353
	28	127.048	61.0459	1.000	-271.293	525.389
	29	-124.216	61.0459	1.000	-522.557	274.125
	30	-13.788	61.0459	1.000	-412.129	384.553
24	25	769.172*	61.0459	.000	370.831	1167.513
	26	231.156	61.0459	.989	-167.185	629.497
	27	545.260*	61.0459	.000	146.919	943.601
	28	677.296*	61.0459	.000	278.955	1075.637
	29	426.032*	61.0459	.013	27.691	824.373
	30	536.460*	61.0459	.000	138.119	934.801
25	26	-538.016*	61.0459	.000	-936.357	-139.675
	27	-223.912	61.0459	.994	-622.253	174.429
	28	-91.876	61.0459	1.000	-490.217	306.465
	29	-343.140	61.0459	.338	-741.481	55.201
	30	-232.712	61.0459	.988	-631.053	165.629
26	27	314.104	61.0459	.600	-84.237	712.445
	28	446.140*	61.0459	.004	47.799	844.481
	29	194.876	61.0459	1.000	-203.465	593.217
	30	305.304	61.0459	.678	-93.037	703.645
27	28	132.036	61.0459	1.000	-266.305	530.377
	29	-119.228	61.0459	1.000	-517.569	279.113
	30	-8.800	61.0459	1.000	-407.141	389.541
28	29	-251.264	61.0459	.963	-649.605	147.077
	30	-140.836	61.0459	1.000	-539.177	257.505
29	30	110.428	61.0459	1.000	-287.913	508.769

Table A2. Result of Randomized Completed Block Design (RCBD) for dwell times (DT)

Multiple Comparisons

Dependent Variable: DT

Scheffe

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.	Interval Lower Bound	Interval Upper Bound
1	2	73.0327*	4.46084	.000	43.9253	102.1402
	3	32.0364*	4.46084	.006	2.9289	61.1438
	4	-64.3600*	4.46084	.000	-93.4675	-35.2525
	5	15.4073	4.46084	.998	-13.7002	44.5147
	6	-46.8691*	4.46084	.000	-75.9765	-17.7616
	7	38.0945*	4.46084	.000	8.9871	67.2020
	8	-8.6764	4.46084	1.000	-37.7838	20.4311
	9	-68.9818*	4.46084	.000	-98.0893	-39.8744
	10	-17.2364	4.46084	.986	-46.3438	11.8711
	11	-13.9091	4.46084	1.000	-43.0165	15.1984
	12	-15.6036	4.46084	.997	-44.7111	13.5038
	13	17.2400	4.46084	.985	-11.8675	46.3475
	14	18.4036	4.46084	.962	-10.7038	47.5111
	15	-36.7927*	4.46084	.000	-65.9002	-7.6853
	16	3.0255	4.46084	1.000	-26.0820	32.1329
	17	-1.5091	4.46084	1.000	-30.6165	27.5984
	18	-39.6655*	4.46084	.000	-68.7729	-10.5580
	19	-56.8982*	4.46084	.000	-86.0056	-27.7907
	20	-41.6836*	4.46084	.000	-70.7911	-12.5762
	21	-71.0036*	4.46084	.000	-100.1111	-41.8962
	22	1.9855	4.46084	1.000	-27.1220	31.0929
	23	-2.9891	4.46084	1.000	-32.0965	26.1184
	24	9.6255	4.46084	1.000	-19.4820	38.7329
	25	-13.3018	4.46084	1.000	-42.4093	15.8056
	26	54.3600*	4.46084	.000	25.2525	83.4675
	27	29.7564*	4.46084	.033	.6489	58.8638
	28	23.9636	4.46084	.473	-5.1438	53.0711
	29	-37.7673*	4.46084	.000	-66.8747	-8.6598
	30	-65.8000*	4.46084	.000	-94.9075	-36.6925
2	3	-40.9964*	4.46084	.000	-70.1038	-11.8889
	4	-137.3927*	4.46084	.000	-166.5002	-108.2853
	5	-57.6255*	4.46084	.000	-86.7329	-28.5180
	6	-119.9018*	4.46084	.000	-149.0093	-90.7944
	7	-34.9382*	4.46084	.000	-64.0456	-5.8307
	8	-81.7091*	4.46084	.000	-110.8165	-52.6016
	9	-142.0145*	4.46084	.000	-171.1220	-112.9071
	10	-90.2691*	4.46084	.000	-119.3765	-61.1616
	11	-86.9418*	4.46084	.000	-116.0493	-57.8344
	12	-88.6364*	4.46084	.000	-117.7438	-59.5289
	13	-55.7927*	4.46084	.000	-84.9002	-26.6853
	14	-54.6291*	4.46084	.000	-83.7365	-25.5216
	15	-109.8255*	4.46084	.000	-138.9329	-80.7180
	16	-70.0073*	4.46084	.000	-99.1147	-40.8998
	17	-74.5418*	4.46084	.000	-103.6493	-45.4344
	18	-112.6982*	4.46084	.000	-141.8056	-83.5907
	19	-129.9309*	4.46084	.000	-159.0384	-100.8235
	20	-114.7164*	4.46084	.000	-143.8238	-85.6089
	21	-144.0364*	4.46084	.000	-173.1438	-114.9289
	22	-71.0473*	4.46084	.000	-100.1547	-41.9398
	23	-76.0218*	4.46084	.000	-105.1293	-46.9144
	24	-63.4073*	4.46084	.000	-92.5147	-34.2998
	25	-86.3345*	4.46084	.000	-115.4420	-57.2271
	26	-18.6727	4.46084	.953	-47.7802	10.4347
	27	-43.2764*	4.46084	.000	-72.3838	-14.1689
	28	-49.0691*	4.46084	.000	-78.1765	-19.9616
	29	-110.8000*	4.46084	.000	-139.9075	-81.6925
	30	-138.8327*	4.46084	.000	-167.9402	-109.7253

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.	Interval Lower Bound	Interval Upper Bound
3	4	-96.3964*	4.46084	.000	-125.5038	-67.2889
	5	-16.6291	4.46084	.992	-45.7365	12.4784
	6	-78.9055*	4.46084	.000	-108.0129	-49.7980
	7	6.0582	4.46084	1.000	-23.0493	35.1656
	8	-40.7127*	4.46084	.000	-69.8202	-11.6053
	9	-101.0182*	4.46084	.000	-130.1256	-71.9107
	10	-49.2727*	4.46084	.000	-78.3802	-20.1653
	11	-45.9455*	4.46084	.000	-75.0529	-16.8380
	12	-47.6400*	4.46084	.000	-76.7475	-18.5325
	13	-14.7964	4.46084	.999	-43.9038	14.3111
	14	-13.6327	4.46084	1.000	-42.7402	15.4747
	15	-68.8291*	4.46084	.000	-97.9365	-39.7216
	16	-29.0109	4.46084	.053	-58.1184	.0965
	17	-33.5455*	4.46084	.002	-62.6529	-4.4380
	18	-71.7018*	4.46084	.000	-100.8093	-42.5944
	19	-88.9345*	4.46084	.000	-118.0420	-59.8271
	20	-73.7200*	4.46084	.000	-102.8275	-44.6125
	21	-103.0400*	4.46084	.000	-132.1475	-73.9325
	22	-30.0509*	4.46084	.027	-59.1584	-.9435
	23	-35.0255*	4.46084	.000	-64.1329	-5.9180
	24	-22.4109	4.46084	.666	-51.5184	6.6965
	25	-45.3382*	4.46084	.000	-74.4456	-16.2307
	26	22.3236	4.46084	.676	-6.7838	51.4311
	27	-2.2800	4.46084	1.000	-31.3875	26.8275
	28	-8.0727	4.46084	1.000	-37.1802	21.0347
	29	-69.8036*	4.46084	.000	-98.9111	-40.6962
	30	-97.8364*	4.46084	.000	-126.9438	-68.7289
4	5	79.7673*	4.46084	.000	50.6598	108.8747
	6	17.4909	4.46084	.982	-11.6165	46.5984
	7	102.4545*	4.46084	.000	73.3471	131.5620
	8	55.6836*	4.46084	.000	26.5762	84.7911
	9	-4.6218	4.46084	1.000	-33.7293	24.4856
	10	47.1236*	4.46084	.000	18.0162	76.2311
	11	50.4509*	4.46084	.000	21.3435	79.5584
	12	48.7564*	4.46084	.000	19.6489	77.8638
	13	81.6000*	4.46084	.000	52.4925	110.7075
	14	82.7636*	4.46084	.000	53.6562	111.8711
	15	27.5673	4.46084	.118	-1.5402	56.6747
	16	67.3855*	4.46084	.000	38.2780	96.4929
	17	62.8509*	4.46084	.000	33.7435	91.9584
	18	24.6945	4.46084	.382	-4.4129	53.8020
	19	7.4618	4.46084	1.000	-21.6456	36.5693
	20	22.6764	4.46084	.634	-6.4311	51.7838
	21	-6.6436	4.46084	1.000	-35.7511	22.4638
	22	66.3455*	4.46084	.000	37.2380	95.4529
	23	61.3709*	4.46084	.000	32.2635	90.4784
	24	73.9855*	4.46084	.000	44.8780	103.0929
	25	51.0582*	4.46084	.000	21.9507	80.1656
	26	118.7200*	4.46084	.000	89.6125	147.8275
	27	94.1164*	4.46084	.000	65.0089	123.2238
	28	88.3236*	4.46084	.000	59.2162	117.4311
	29	26.5927	4.46084	.188	-2.5147	55.7002
	30	-1.4400	4.46084	1.000	-30.5475	27.6675

Table A2. Result of Randomized Completed Block Design (RCBD) for dwell times (DT)

Multiple Comparisons

Dependent Variable: DT

Scheffe

(I) Class		Mean Difference (I-J)	Std. Error	Sig.	Interval	
					Lower Bound	Upper Bound
5	6	-62.2764*	4.46084	.000	-91.3838	-33.1689
	7	22.6873	4.46084	.633	-6.4202	51.7947
	8	-24.0836	4.46084	.457	-53.1911	5.0238
	9	-84.3891*	4.46084	.000	-113.4965	-55.2816
	10	-32.6436*	4.46084	.004	-61.7511	-3.5362
	11	-29.3164*	4.46084	.044	-58.4238	-.2089
	12	-31.0109*	4.46084	.014	-60.1184	-1.9035
	13	1.8327	4.46084	1.000	-27.2747	30.9402
	14	2.9964	4.46084	1.000	-26.1111	32.1038
	15	-52.2000*	4.46084	.000	-81.3075	-23.0925
	16	-12.3818	4.46084	1.000	-41.4893	16.7256
	17	-16.9164	4.46084	.989	-46.0238	12.1911
	18	-55.0727*	4.46084	.000	-84.1802	-25.9653
	19	-72.3055*	4.46084	.000	-101.4129	-43.1980
	20	-57.0909*	4.46084	.000	-86.1984	-27.9835
	21	-86.4109*	4.46084	.000	-115.5184	-57.3035
	22	-13.4218	4.46084	1.000	-42.5293	15.6856
	23	-18.3964	4.46084	.962	-47.5038	10.7111
	24	-5.7818	4.46084	1.000	-34.8893	23.3256
	25	-28.7091	4.46084	.063	-57.8165	.3984
	26	38.9527*	4.46084	.000	9.8453	68.0602
	27	14.3491	4.46084	.999	-14.7584	43.4565
	28	8.5564	4.46084	1.000	-20.5511	37.6638
	29	-53.1745*	4.46084	.000	-82.2820	-24.0671
	30	-81.2073*	4.46084	.000	-110.3147	-52.0998
6	7	84.9636*	4.46084	.000	55.8562	114.0711
	8	38.1927*	4.46084	.000	9.0853	67.3002
	9	-22.1127	4.46084	.700	-51.2202	6.9947
	10	29.6327*	4.46084	.036	.5253	58.7402
	11	32.9600*	4.46084	.003	3.8525	62.0675
	12	31.2655*	4.46084	.011	2.1580	60.3729
	13	64.1091*	4.46084	.000	35.0016	93.2165
	14	65.2727*	4.46084	.000	36.1653	94.3802
	15	10.0764	4.46084	1.000	-19.0311	39.1838
	16	49.8945*	4.46084	.000	20.7871	79.0020
	17	45.3600*	4.46084	.000	16.2525	74.4675
	18	7.2036	4.46084	1.000	-21.9038	36.3111
	19	-10.0291	4.46084	1.000	-39.1365	19.0784
	20	5.1855	4.46084	1.000	-23.9220	34.2929
	21	-24.1345	4.46084	.451	-53.2420	4.9729
	22	48.8545*	4.46084	.000	19.7471	77.9620
	23	43.8800*	4.46084	.000	14.7725	72.9875
	24	56.4945*	4.46084	.000	27.3871	85.6020
	25	33.5673*	4.46084	.002	4.4598	62.6747
	26	101.2291*	4.46084	.000	72.1216	130.3365
	27	76.6255*	4.46084	.000	47.5180	105.7329
	28	70.8327*	4.46084	.000	41.7253	99.9402
	29	9.1018	4.46084	1.000	-20.0056	38.2093
	30	-18.9309	4.46084	.944	-48.0384	10.1765
7	8	-46.7709*	4.46084	.000	-75.8784	-17.6635
	9	-107.0764*	4.46084	.000	-136.1838	-77.9689
	10	-55.3309*	4.46084	.000	-84.4384	-26.2235
	11	-52.0036*	4.46084	.000	-81.1111	-22.8962
	12	-53.6982*	4.46084	.000	-82.8056	-24.5907
	13	-20.8545	4.46084	.826	-49.9620	8.2529
	14	-19.6909	4.46084	.908	-48.7984	9.4165
	15	-74.8873*	4.46084	.000	-103.9947	-45.7798
	16	-35.0691*	4.46084	.000	-64.1765	-5.9616
	17	-39.6036*	4.46084	.000	-68.7111	-10.4962
	18	-77.7600*	4.46084	.000	-106.8675	-48.6525
	19	-94.9927*	4.46084	.000	-124.1002	-65.8853
	20	-79.7782*	4.46084	.000	-108.8856	-50.6707
	21	-109.0982*	4.46084	.000	-138.2056	-79.9907
	22	-36.1091*	4.46084	.000	-65.2165	-7.0016
	23	-41.0836*	4.46084	.000	-70.1911	-11.9762
	24	-28.4691	4.46084	.073	-57.5765	.6384
	25	-51.3964*	4.46084	.000	-80.5038	-22.2889
	26	16.2655	4.46084	.994	-12.8420	45.3729
	27	-8.3382	4.46084	1.000	-37.4456	20.7693
	28	-14.1309	4.46084	1.000	-43.2384	14.9765
	29	-75.8618*	4.46084	.000	-104.9693	-46.7544
	30	-103.8945*	4.46084	.000	-133.0020	-74.7871
8	9	-60.3055*	4.46084	.000	-89.4129	-31.1980
	10	-8.5600	4.46084	1.000	-37.6675	20.5475
	11	-5.2327	4.46084	1.000	-34.3402	23.8747
	12	-6.9273	4.46084	1.000	-36.0347	22.1802
	13	25.9164	4.46084	.249	-3.1911	55.0238
	14	27.0800	4.46084	.150	-2.0275	56.1875
	15	-28.1164	4.46084	.089	-57.2238	.9911
	16	11.7018	4.46084	1.000	-17.4056	40.8093
	17	7.1673	4.46084	1.000	-21.9402	36.2747
	18	-30.9891*	4.46084	.014	-60.0965	-1.8816
	19	-48.2218*	4.46084	.000	-77.3293	-19.1144
	20	-33.0073*	4.46084	.003	-62.1147	-3.8998
	21	-62.3273*	4.46084	.000	-91.4347	-33.2198
	22	10.6618	4.46084	1.000	-18.4456	39.7693
	23	5.6873	4.46084	1.000	-23.4202	34.7947
	24	18.3018	4.46084	.965	-10.8056	47.4093
	25	-4.6255	4.46084	1.000	-33.7329	24.4820
	26	63.0364*	4.46084	.000	33.9289	92.1438
	27	38.4327*	4.46084	.000	9.3253	67.5402
	28	32.6400*	4.46084	.004	3.5325	61.7475
	29	-29.0909	4.46084	.051	-58.1984	.0165
	30	-57.1236*	4.46084	.000	-86.2311	-28.0162

Table A2. Result of Randomized Completed Block Design (RCBD) for dwell times (DT)

Multiple Comparisons

Dependent Variable: DT

Scheffe

(I) Class		Mean Difference (I-J)	Std. Error	Sig.	Interval Lower Bound	Interval Upper Bound
9	10	51.7455*	4.46084	.000	22.6380	80.8529
	11	55.0727*	4.46084	.000	25.9653	84.1802
	12	53.3782*	4.46084	.000	24.2707	82.4856
	13	86.2218*	4.46084	.000	57.1144	115.3293
	14	87.3855*	4.46084	.000	58.2780	116.4929
	15	32.1891*	4.46084	.005	3.0816	61.2965
	16	72.0073*	4.46084	.000	42.8998	101.1147
	17	67.4727*	4.46084	.000	38.3653	96.5802
	18	29.3164*	4.46084	.044	.2089	58.4238
	19	12.0836	4.46084	1.000	-17.0238	41.1911
	20	27.2982	4.46084	.135	-1.8093	56.4056
	21	-2.0218	4.46084	1.000	-31.1293	27.0856
	22	70.9673*	4.46084	.000	41.8598	100.0747
	23	65.9927*	4.46084	.000	36.8853	95.1002
	24	78.6073*	4.46084	.000	49.4998	107.7147
	25	55.6800*	4.46084	.000	26.5725	84.7875
	26	123.3418*	4.46084	.000	94.2344	152.4493
	27	98.7382*	4.46084	.000	69.6307	127.8456
	28	92.9455*	4.46084	.000	63.8380	122.0529
	29	31.2145*	4.46084	.012	2.1071	60.3220
	30	3.1818	4.46084	1.000	-25.9256	32.2893
10	11	3.3273	4.46084	1.000	-25.7802	32.4347
	12	1.6327	4.46084	1.000	-27.4747	30.7402
	13	34.4764*	4.46084	.001	5.3689	63.5838
	14	35.6400*	4.46084	.000	6.5325	64.7475
	15	-19.5564	4.46084	.915	-48.6638	9.5511
	16	20.2618	4.46084	.872	-8.8456	49.3693
	17	15.7273	4.46084	.997	-13.3802	44.8347
	18	-22.4291	4.46084	.664	-51.5365	6.6784
	19	-39.6618*	4.46084	.000	-68.7693	-10.5544
	20	-24.4473	4.46084	.412	-53.5547	4.6602
	21	-53.7673*	4.46084	.000	-82.8747	-24.6598
	22	19.2218	4.46084	.932	-9.8856	48.3293
	23	14.2473	4.46084	1.000	-14.8602	43.3547
	24	26.8618	4.46084	.166	-2.2456	55.9693
	25	3.9345	4.46084	1.000	-25.1729	33.0420
	26	71.5964*	4.46084	.000	42.4889	100.7038
	27	46.9927*	4.46084	.000	17.8853	76.1002
	28	41.2000*	4.46084	.000	12.0925	70.3075
	29	-20.5309	4.46084	.852	-49.6384	8.5765
	30	-48.5636*	4.46084	.000	-77.6711	-19.4562
11	12	-1.6945	4.46084	1.000	-30.8020	27.4129
	13	31.1491*	4.46084	.012	2.0416	60.2565
	14	32.3127*	4.46084	.005	3.2053	61.4202
	15	-22.8836	4.46084	.609	-51.9911	6.2238
	16	16.9345	4.46084	.989	-12.1729	46.0420
	17	12.4000	4.46084	1.000	-16.7075	41.5075
	18	-25.7564	4.46084	.265	-54.8638	3.3511
	19	-42.9891*	4.46084	.000	-72.0965	-13.8816
	20	-27.7745	4.46084	.106	-56.8820	1.3329
	21	-57.0945*	4.46084	.000	-86.2020	-27.9871
	22	15.8945	4.46084	.996	-13.2129	45.0020
	23	10.9200	4.46084	1.000	-18.1875	40.0275
	24	23.5345	4.46084	.527	-5.5729	52.6420
	25	.6073	4.46084	1.000	-28.5002	29.7147
	26	68.2691*	4.46084	.000	39.1616	97.3765
	27	43.6655*	4.46084	.000	14.5580	72.7729
	28	37.8727*	4.46084	.000	8.7653	66.9802
	29	-23.8582	4.46084	.486	-52.9656	5.2493
	30	-51.8909*	4.46084	.000	-80.9984	-22.7835
12	13	32.8436*	4.46084	.003	3.7362	61.9511
	14	34.0073*	4.46084	.001	4.8998	63.1147
	15	-21.1891	4.46084	.796	-50.2965	7.9184
	16	18.6291	4.46084	.955	-10.4784	47.7365
	17	14.0945	4.46084	1.000	-15.0129	43.2020
	18	-24.0618	4.46084	.460	-53.1693	5.0456
	19	-41.2945*	4.46084	.000	-70.4020	-12.1871
	20	-26.0800	4.46084	.233	-55.1875	3.0275
	21	-55.4000*	4.46084	.000	-84.5075	-26.2925
	22	17.5891	4.46084	.980	-11.5184	46.6965
	23	12.6145	4.46084	1.000	-16.4929	41.7220
	24	25.2291	4.46084	.321	-3.8784	54.3365
	25	2.3018	4.46084	1.000	-26.8056	31.4093
	26	69.9636*	4.46084	.000	40.8562	99.0711
	27	45.3600*	4.46084	.000	16.2525	74.4675
	28	39.5673*	4.46084	.000	10.4598	68.6747
	29	-22.1636	4.46084	.694	-51.2711	6.9438
	30	-50.1964*	4.46084	.000	-79.3038	-21.0889

Table A2. Result of Randomized Completed Block Design (RCBD) for dwell times (DT)

Multiple Comparisons

Dependent Variable: DT

Scheffe

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.	Interval Lower Bound	Interval Upper Bound
13	14	1.1636	4.46084	1.000	-27.9438	30.2711
	15	-54.0327*	4.46084	.000	-83.1402	-24.9253
	16	-14.2145	4.46084	1.000	-43.3220	14.8929
	17	-18.7491	4.46084	.951	-47.8565	10.3584
	18	-56.9055*	4.46084	.000	-86.0129	-27.7980
	19	-74.1382*	4.46084	.000	-103.2456	-45.0307
	20	-58.9236*	4.46084	.000	-88.0311	-29.8162
	21	-88.2436*	4.46084	.000	-117.3511	-59.1362
	22	-15.2545	4.46084	.998	-44.3620	13.8529
	23	-20.2291	4.46084	.874	-49.3365	8.8784
	24	-7.6145	4.46084	1.000	-36.7220	21.4929
	25	-30.5418*	4.46084	.019	-59.6493	-1.4344
	26	37.1200*	4.46084	.000	8.0125	66.2275
	27	12.5164	4.46084	1.000	-16.5911	41.6238
	28	6.7236	4.46084	1.000	-22.3838	35.8311
	29	-55.0073*	4.46084	.000	-84.1147	-25.8998
	30	-83.0400*	4.46084	.000	-112.1475	-53.9325
14	15	-55.1964*	4.46084	.000	-84.3038	-26.0889
	16	-15.3782	4.46084	.998	-44.4856	13.7293
	17	-19.9127	4.46084	.895	-49.0202	9.1947
	18	-58.0691*	4.46084	.000	-87.1765	-28.9616
	19	-75.3018*	4.46084	.000	-104.4093	-46.1944
	20	-60.0873*	4.46084	.000	-89.1947	-30.9798
	21	-89.4073*	4.46084	.000	-118.5147	-60.2998
	22	-16.4182	4.46084	.993	-45.5256	12.6893
	23	-21.3927	4.46084	.776	-50.5002	7.7147
	24	-8.7782	4.46084	1.000	-37.8856	20.3293
	25	-31.7055*	4.46084	.008	-60.8129	-2.5980
	26	35.9564*	4.46084	.000	6.8489	65.0638
	27	11.3527	4.46084	1.000	-17.7547	40.4602
	28	5.5600	4.46084	1.000	-23.5475	34.6675
	29	-56.1709*	4.46084	.000	-85.2784	-27.0635
	30	-84.2036*	4.46084	.000	-113.3111	-55.0962
15	16	39.8182*	4.46084	.000	10.7107	68.9256
	17	35.2836*	4.46084	.000	6.1762	64.3911
	18	-2.8727	4.46084	1.000	-31.9802	26.2347
	19	-20.1055	4.46084	.883	-49.2129	9.0020
	20	-4.8909	4.46084	1.000	-33.9984	24.2165
	21	-34.2109*	4.46084	.001	-63.3184	-5.1035
	22	38.7782*	4.46084	.000	9.6707	67.8856
	23	33.8036*	4.46084	.001	4.6962	62.9111
	24	46.4182*	4.46084	.000	17.3107	75.5256
	25	23.4909	4.46084	.532	-5.6165	52.5984
	26	91.1527*	4.46084	.000	62.0453	120.2602
	27	66.5491*	4.46084	.000	37.4416	95.6565
	28	60.7564*	4.46084	.000	31.6489	89.8638
	29	-.9745	4.46084	1.000	-30.0820	28.1329
	30	-29.0073	4.46084	.053	-58.1147	.1002
16	17	-4.5345	4.46084	1.000	-33.6420	24.5729
	18	-42.6909*	4.46084	.000	-71.7984	-13.5835
	19	-59.9236*	4.46084	.000	-89.0311	-30.8162
	20	-44.7091*	4.46084	.000	-73.8165	-15.6016
	21	-74.0291*	4.46084	.000	-103.1365	-44.9216
	22	-1.0400	4.46084	1.000	-30.1475	28.0675
	23	-6.0145	4.46084	1.000	-35.1220	23.0929
	24	6.6000	4.46084	1.000	-22.5075	35.7075
	25	-16.3273	4.46084	.994	-45.4347	12.7802
	26	51.3345*	4.46084	.000	22.2271	80.4420
	27	26.7309	4.46084	.177	-2.3765	55.8384
	28	20.9382	4.46084	.819	-8.1693	50.0456
	29	-40.7927*	4.46084	.000	-69.9002	-11.6853
	30	-68.8255*	4.46084	.000	-97.9329	-39.7180
17	18	-38.1564*	4.46084	.000	-67.2638	-9.0489
	19	-55.3891*	4.46084	.000	-84.4965	-26.2816
	20	-40.1745*	4.46084	.000	-69.2820	-11.0671
	21	-69.4945*	4.46084	.000	-98.6020	-40.3871
	22	3.4945	4.46084	1.000	-25.6129	32.6020
	23	-1.4800	4.46084	1.000	-30.5875	27.6275
	24	11.1345	4.46084	1.000	-17.9729	40.2420
	25	-11.7927	4.46084	1.000	-40.9002	17.3147
	26	55.8691*	4.46084	.000	26.7616	84.9765
	27	31.2655*	4.46084	.011	2.1580	60.3729
	28	25.4727	4.46084	.294	-3.6347	54.5802
	29	-36.2582*	4.46084	.000	-65.3656	-7.1507
	30	-64.2909*	4.46084	.000	-93.3984	-35.1835
18	19	-17.2327	4.46084	.986	-46.3402	11.8747
	20	-2.0182	4.46084	1.000	-31.1256	27.0893
	21	-31.3382*	4.46084	.011	-60.4456	-2.2307
	22	41.6509*	4.46084	.000	12.5435	70.7584
	23	36.6764*	4.46084	.000	7.5689	65.7838
	24	49.2909*	4.46084	.000	20.1835	78.3984
	25	26.3636	4.46084	.207	-2.7438	55.4711
	26	94.0255*	4.46084	.000	64.9180	123.1329
	27	69.4218*	4.46084	.000	40.3144	98.5293
	28	63.6291*	4.46084	.000	34.5216	92.7365
	29	1.8982	4.46084	1.000	-27.2093	31.0056
	30	-26.1345	4.46084	.228	-55.2420	2.9729
19	20	15.2145	4.46084	.998	-13.8929	44.3220
	21	-14.1055	4.46084	1.000	-43.2129	15.0020
	22	58.8836*	4.46084	.000	29.7762	87.9911
	23	53.9091*	4.46084	.000	24.8016	83.0165
	24	66.5236*	4.46084	.000	37.4162	95.6311
	25	43.5964*	4.46084	.000	14.4889	72.7038
	26	111.2582*	4.46084	.000	82.1507	140.3656
	27	86.6545*	4.46084	.000	57.5471	115.7620
	28	80.8618*	4.46084	.000	51.7544	109.9693
	29	19.1309	4.46084	.936	-9.9765	48.2384
	30	-8.9018	4.46084	1.000	-38.0093	20.2056

Table A2. Result of Randomized Completed Block Design (RCBD) for dwell times (DT)

Multiple Comparisons

Dependent Variable: DT

Scheffe

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.	Interval Lower Bound	Interval Upper Bound
20	21	-29.3200*	4.46084	.044	-58.4275	-.2125
	22	43.6691*	4.46084	.000	14.5616	72.7765
	23	38.6945*	4.46084	.000	9.5871	67.8020
	24	51.3091*	4.46084	.000	22.2016	80.4165
	25	28.3818	4.46084	.077	-.7256	57.4893
	26	96.0436*	4.46084	.000	66.9362	125.1511
	27	71.4400*	4.46084	.000	42.3325	100.5475
	28	65.6473*	4.46084	.000	36.5398	94.7547
	29	3.9164	4.46084	1.000	-25.1911	33.0238
	30	-24.1164	4.46084	.453	-53.2238	4.9911
21	22	72.9891*	4.46084	.000	43.8816	102.0965
	23	68.0145*	4.46084	.000	38.9071	97.1220
	24	80.6291*	4.46084	.000	51.5216	109.7365
	25	57.7018*	4.46084	.000	28.5944	86.8093
	26	125.3636*	4.46084	.000	96.2562	154.4711
	27	100.7600*	4.46084	.000	71.6525	129.8675
	28	94.9673*	4.46084	.000	65.8598	124.0747
	29	33.2364*	4.46084	.002	4.1289	62.3438
	30	5.2036	4.46084	1.000	-23.9038	34.3111
22	23	-4.9745	4.46084	1.000	-34.0820	24.1329
	24	7.6400	4.46084	1.000	-21.4675	36.7475
	25	-15.2873	4.46084	.998	-44.3947	13.8202
	26	52.3745*	4.46084	.000	23.2671	81.4820
	27	27.7709	4.46084	.107	-1.3365	56.8784
	28	21.9782	4.46084	.715	-7.1293	51.0856
	29	-39.7527*	4.46084	.000	-68.8602	-10.6453
	30	-67.7855*	4.46084	.000	-96.8929	-38.6780
23	24	12.6145	4.46084	1.000	-16.4929	41.7220
	25	-10.3127	4.46084	1.000	-39.4202	18.7947
	26	57.3491*	4.46084	.000	28.2416	86.4565
	27	32.7455*	4.46084	.003	3.6380	61.8529
	28	26.9527	4.46084	.160	-2.1547	56.0602
	29	-34.7782*	4.46084	.001	-63.8856	-5.6707
	30	-62.8109*	4.46084	.000	-91.9184	-33.7035
24	25	-22.9273	4.46084	.603	-52.0347	6.1802
	26	44.7345*	4.46084	.000	15.6271	73.8420
	27	20.1309	4.46084	.881	-8.9765	49.2384
	28	14.3382	4.46084	.999	-14.7693	43.4456
	29	-47.3927*	4.46084	.000	-76.5002	-18.2853
	30	-75.4255*	4.46084	.000	-104.5329	-46.3180
25	26	67.6618*	4.46084	.000	38.5544	96.7693
	27	43.0582*	4.46084	.000	13.9507	72.1656
	28	37.2655*	4.46084	.000	8.1580	66.3729
	29	-24.4655	4.46084	.410	-53.5729	4.6420
	30	-52.4982*	4.46084	.000	-81.6056	-23.3907
26	27	-24.6036	4.46084	.393	-53.7111	4.5038
	28	-30.3964*	4.46084	.021	-59.5038	-1.2889
	29	-92.1273*	4.46084	.000	-121.2347	-63.0198
	30	-120.1600*	4.46084	.000	-149.2675	-91.0525
27	28	-5.7927	4.46084	1.000	-34.9002	23.3147
	29	-67.5236*	4.46084	.000	-96.6311	-38.4162
	30	-95.5564*	4.46084	.000	-124.6638	-66.4489
28	29	-61.7309*	4.46084	.000	-90.8384	-32.6235
	30	-89.7636*	4.46084	.000	-118.8711	-60.6562
29	30	-28.0327	4.46084	.093	-57.1402	1.0747

Table A3. Result of Randomized Completed Block Design (RCBD) for Area (Area)

Multiple Comparisons

Dependent Variable: Area

Scheffe

(I) Class		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	2	.02570199*	.000791075	.000	.02054002	.03086397
	3	.00262738	.000791075	.999	-.00253460	.00778936
	4	.01342761*	.000791075	.000	.00826563	.01858958
	5	-.00218447	.000791075	1.000	-.00734645	.00297751
	6	.00244698	.000791075	1.000	-.00271500	.00760895
	7	.00156071	.000791075	1.000	-.00360127	.00672269
	8	.00197639	.000791075	1.000	-.00318559	.00713837
	9	.01998050*	.000791075	.000	.01481853	.02514248
	10	.00224306	.000791075	1.000	-.00291892	.00740503
	11	-.01120936*	.000791075	.000	-.01637134	-.00604738
	12	-.00164323	.000791075	1.000	-.00680520	.00351875
	13	.01234515*	.000791075	.000	.00718317	.01750712
	14	-.17840781*	.000791075	0.000	-.18356978	-.17324583
	15	-.00756856*	.000791075	.000	-.01273054	-.00240659
	16	-.00542936*	.000791075	.018	-.01059134	-.00026738
	17	.00326274	.000791075	.962	-.00189924	.00842471
	18	.00399995	.000791075	.648	-.00116203	.00916192
	19	.02276893*	.000791075	.000	.01760696	.02793091
	20	.00415680	.000791075	.539	-.00100517	.00931878
	21	-.00484936	.000791075	.132	-.01001134	.00031262
	22	.02827457*	.000791075	.000	.02311259	.03343655
	23	.01014519*	.000791075	.000	.00498321	.01530716
	24	.03003537*	.000791075	.000	.02487339	.03519734
	25	.00935689*	.000791075	.000	.00419491	.01451886
	26	.01824314*	.000791075	.000	.01308117	.02340512
	27	.02108642*	.000791075	.000	.01592445	.02624840
	28	-.24181960*	.000791075	0.000	-.24698158	-.23665763
	29	-.09090187*	.000791075	0.000	-.09606385	-.08573989
	30	.00722347*	.000791075	.000	.00206150	.01238545
2	3	-.02307461*	.000791075	.000	-.02823659	-.01791264
	4	-.01227439*	.000791075	.000	-.01743636	-.00711241
	5	-.02788646*	.000791075	.000	-.03304844	-.02272449
	6	-.02325502*	.000791075	.000	-.02841699	-.01809304
	7	-.02414128*	.000791075	.000	-.02930326	-.01897931
	8	-.02372560*	.000791075	.000	-.02888758	-.01856363
	9	-.00572149*	.000791075	.005	-.01088347	-.00055952
	10	-.02345894*	.000791075	.000	-.02862091	-.01829696
	11	-.03691135*	.000791075	0.000	-.04207333	-.03174938
	12	-.02734522*	.000791075	.000	-.03250720	-.02218324
	13	-.01335685*	.000791075	.000	-.01851882	-.00819487
	14	-.20410980*	.000791075	0.000	-.20927178	-.19894782
	15	-.03327056*	.000791075	0.000	-.03843253	-.02810858
	16	-.03113135*	.000791075	.000	-.03629333	-.02596938
	17	-.02243926*	.000791075	.000	-.02760123	-.01727728
	18	-.02170205*	.000791075	.000	-.02686402	-.01654007
	19	-.00293306	.000791075	.993	-.00809504	.00222891
	20	-.02154519*	.000791075	.000	-.02670717	-.01638321
	21	-.03055135*	.000791075	.000	-.03571333	-.02538938
	22	.00257258	.000791075	.999	-.00258940	.00773455
	23	-.01555681*	.000791075	.000	-.02071878	-.01039483
	24	.00433337	.000791075	.414	-.00082860	.00949535
	25	-.01634511*	.000791075	.000	-.02150708	-.01118313
	26	-.00745885*	.000791075	.000	-.01262083	-.00229688
	27	-.00461557	.000791075	.238	-.00977755	.00054640
	28	-.26752160*	.000791075	0.000	-.27268357	-.26235962
	29	-.11660386*	.000791075	0.000	-.12176584	-.11144189
	30	-.01847852*	.000791075	.000	-.02364050	-.01331655
3	4	.01080023*	.000791075	.000	.00563825	.01596220
	5	-.00481185	.000791075	.147	-.00997383	.00035013
	6	-.00018040	.000791075	1.000	-.00534238	.00498157
	7	-.00106667	.000791075	1.000	-.00622865	.00409531
	8	-.00065099	.000791075	1.000	-.00581297	.00451099
	9	.01735312*	.000791075	.000	.01219115	.02251510
	10	-.00038432	.000791075	1.000	-.00554630	.00477765
	11	-.01383674*	.000791075	.000	-.01899872	-.00867476
	12	-.00427061	.000791075	.458	-.00943258	.00089137
	13	.00971777*	.000791075	.000	.00455579	.01487974
	14	-.18103519*	.000791075	0.000	-.18619716	-.17587321
	15	-.01019594*	.000791075	.000	-.01535792	-.00503397
	16	-.00805674*	.000791075	.000	-.01321872	-.00289476
	17	.00063536	.000791075	1.000	-.00452662	.00579733
	18	.00137257	.000791075	1.000	-.00378941	.00653454
	19	.02014155*	.000791075	.000	.01497958	.02530353
	20	.00152942	.000791075	1.000	-.00363255	.00669140
	21	-.00747674*	.000791075	.000	-.01263872	-.00231476
	22	.02564719*	.000791075	.000	.02048521	.03080917
	23	.00751781*	.000791075	.000	.00235583	.01267978
	24	.02740799*	.000791075	.000	.02224601	.03256996
	25	.00672951*	.000791075	.000	.00156753	.01189148
	26	.01561576*	.000791075	.000	.01045379	.02077774
	27	.01845904*	.000791075	.000	.01329707	.02362102
	28	-.24444698*	.000791075	0.000	-.24960896	-.23928501
	29	-.09352925*	.000791075	0.000	-.09869123	-.08836727
	30	.00459609	.000791075	.249	-.00056588	.00975807
4	5	-.01561208*	.000791075	.000	-.02077405	-.01045010
	6	-.01098063*	.000791075	.000	-.01614261	-.00581866
	7	-.01186690*	.000791075	.000	-.01702887	-.00670492
	8	-.01145122*	.000791075	.000	-.01661319	-.00628924
	9	.00655289*	.000791075	.000	.00139092	.01171487
	10	-.01118455*	.000791075	.000	-.01634653	-.00602257
	11	-.02463697*	.000791075	.000	-.02979894	-.01947499
	12	-.01507083*	.000791075	.000	-.02023281	-.00990886
	13	-.00108246	.000791075	1.000	-.00624444	.00407952
	14	-.19183541*	.000791075	0.000	-.19699739	-.18667344
	15	-.02099617*	.000791075	.000	-.02615815	-.01583420
	16	-.01885697*	.000791075	.000	-.02401894	-.01369499
	17	-.01016487*	.000791075	.000	-.01532685	-.00500290
	18	-.00942766*	.000791075	.000	-.01458964	-.00426569
	19	.00934132*	.000791075	.000	.00417935	.01450330
	20	-.00927080*	.000791075	.000	-.01443278	-.00410883
	21	-.01827697*	.000791075	.000	-.02343894	-.01311499
	22	.01484696*	.000791075	.000	.00968499	.02000894
	23	-.00328242	.000791075	.959	-.00844440	.00187956
	24	.01660776*	.000791075	.000	.01144578	.02176973
	25	-.00407072	.000791075	.600	-.00923270	.00109125
	26	.00481553	.000791075	.145	-.00034644	.00997751
	27	.00765881*	.000791075	.000	.00249684	.01282079
	28	-.25524721*	.000791075	0.000	-.26040919	-.25008524
	29	-.10432948*	.000791075	0.000	-.10949145	-.09916750
	30	-.00620414*	.000791075	.000	-.01136611	-.00104216

Table A3. Result of Randomized Completed Block Design (RCBD) for Area (Area)

Multiple Comparisons

Dependent Variable: Area

Scheffe

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
5	6	.00463145	.000791075	.230	-.00053053	.00979342
	7	.00374518	.000791075	.803	-.00141680	.00890716
	8	.00416086	.000791075	.536	-.00100112	.00932284
	9	.02216497*	.000791075	.000	.01700300	.02732695
	10	.00442753	.000791075	.350	-.00073445	.00958950
	11	-.00902489*	.000791075	.000	-.01418687	-.00386291
	12	.00054124	.000791075	1.000	-.00462073	.00570322
	13	.01452962*	.000791075	.000	.00936764	.01969159
	14	-.17622334*	.000791075	0.000	-.18138531	-.17106136
	15	-.00538409*	.000791075	.022	-.01054607	-.00022212
	16	-.00324489	.000791075	.965	-.00840687	.00191709
	17	.00544721*	.000791075	.017	.00028523	.01060918
	18	.00618442*	.000791075	.000	.00102244	.01134639
	19	.02495340*	.000791075	.000	.01979143	.03011538
	20	.00634127*	.000791075	.000	.00117930	.01150325
	21	-.00266489	.000791075	.999	-.00782687	.00249709
	22	.03045904*	.000791075	.000	.02529706	.03562102
	23	.01232966*	.000791075	.000	.00716768	.01749163
	24	.03221984*	.000791075	0.000	.02705786	.03738181
	25	.01154136*	.000791075	.000	.00637938	.01670333
	26	.02042761*	.000791075	.000	.01526564	.02558959
	27	.02327089*	.000791075	.000	.01810892	.02843287
	28	-.23963513*	.000791075	0.000	-.24479711	-.23447316
	29	-.08871740*	.000791075	0.000	-.09387938	-.08355542
	30	.00940794*	.000791075	.000	.00424597	.01456992
6	7	-.00088627	.000791075	1.000	-.00604824	.00427571
	8	-.00047059	.000791075	1.000	-.00563256	.00469139
	9	.01753353*	.000791075	.000	.01237155	.02269550
	10	-.00020392	.000791075	1.000	-.00536589	.00495806
	11	-.01365634*	.000791075	.000	-.01881831	-.00849436
	12	-.00409020	.000791075	.586	-.00925218	.00107177
	13	.00989817*	.000791075	.000	.00473620	.01506015
	14	-.18085478*	.000791075	0.000	-.18601676	-.17569281
	15	-.01001554*	.000791075	.000	-.01517752	-.00485356
	16	-.00787634*	.000791075	.000	-.01303831	-.00271436
	17	.00081576	.000791075	1.000	-.00434622	.00597774
	18	.00155297	.000791075	1.000	-.00360901	.00671495
	19	.02032196*	.000791075	.000	.01515998	.02548393
	20	.00170983	.000791075	1.000	-.00345215	.00687180
	21	-.00729634*	.000791075	.000	-.01245831	-.00213436
	22	.02582759*	.000791075	.000	.02066562	.03098957
	23	.00769821*	.000791075	.000	.00253624	.01286019
	24	.02758839*	.000791075	.000	.02242641	.03275037
	25	.00690991*	.000791075	.000	.00174793	.01207189
	26	.01579617*	.000791075	.000	.01063419	.02095814
	27	.01863945*	.000791075	.000	.01347747	.02380142
	28	-.24426658*	.000791075	0.000	-.24942856	-.23910460
	29	-.09334885*	.000791075	0.000	-.09851082	-.08818687
	30	.00477650	.000791075	.161	-.00038548	.00993847
7	8	.00041568	.000791075	1.000	-.00474630	.00557766
	9	.01841979*	.000791075	.000	.01325782	.02358177
	10	.00068235	.000791075	1.000	-.00447963	.00584432
	11	-.01277007*	.000791075	.000	-.01793205	-.00760809
	12	-.00320394	.000791075	.971	-.00836591	.00195804
	13	.01078444*	.000791075	.000	.00562246	.01594641
	14	-.17996852*	.000791075	0.000	-.18513049	-.17480654
	15	-.00912927*	.000791075	.000	-.01429125	-.00396730
	16	-.00699007*	.000791075	.000	-.01215205	-.00182809
	17	.00170203	.000791075	1.000	-.00345995	.00686400
	18	.00243924	.000791075	1.000	-.00272274	.00760121
	19	.02120822*	.000791075	.000	.01604625	.02637020
	20	.00259609	.000791075	.999	-.00256588	.00775807
	21	-.00641007*	.000791075	.000	-.01157205	-.00124809
	22	.02671386*	.000791075	.000	.02155188	.03187584
	23	.00858448*	.000791075	.000	.00342250	.01374645
	24	.02847466*	.000791075	.000	.02331268	.03363663
	25	.00779618*	.000791075	.000	.00263420	.01295815
	26	.01668243*	.000791075	.000	.01152046	.02184441
	27	.01952571*	.000791075	.000	.01436374	.02468769
	28	-.24338031*	.000791075	0.000	-.24854229	-.23821834
	29	-.09246258*	.000791075	0.000	-.09762456	-.08730060
	30	.00566276*	.000791075	.007	.00050079	.01082474
8	9	.01800411*	.000791075	.000	.01284214	.02316609
	10	.00026667	.000791075	1.000	-.00489531	.00542864
	11	-.01318575*	.000791075	.000	-.01834773	-.00802377
	12	-.00361962	.000791075	.861	-.00878159	.00154236
	13	.01036876*	.000791075	.000	.00520678	.01553073
	14	-.18038420*	.000791075	0.000	-.18554617	-.17522222
	15	-.00954495*	.000791075	.000	-.01470693	-.00438298
	16	-.00740575*	.000791075	.000	-.01256773	-.00224377
	17	.00128635	.000791075	1.000	-.00387563	.00644832
	18	.00202356	.000791075	1.000	-.00313842	.00718553
	19	.02079254*	.000791075	.000	.01563057	.02595452
	20	.00218041	.000791075	1.000	-.00298156	.00734239
	21	-.00682575*	.000791075	.000	-.01198773	-.00166377
	22	.02629818*	.000791075	.000	.02113620	.03146016
	23	.00816880*	.000791075	.000	.00300682	.01333077
	24	.02805898*	.000791075	.000	.02289700	.03322095
	25	.00738050*	.000791075	.000	.00221852	.01254247
	26	.01626675*	.000791075	.000	.01110478	.02142873
	27	.01911003*	.000791075	.000	.01394806	.02427201
	28	-.24379599*	.000791075	0.000	-.24895797	-.23863402
	29	-.09287826*	.000791075	0.000	-.09804024	-.08771628
	30	.00524708*	.000791075	.037	.00008511	.01040906

Table A3. Result of Randomized Completed Block Design (RCBD) for Area (Area)

Multiple Comparisons

Dependent Variable: Area

Scheffe

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
9	10	-.01773744*	.000791075	.000	-.02289942	-.01257547
	11	-.03118986*	.000791075	.000	-.03635184	-.02602789
	12	-.02162373*	.000791075	.000	-.02678570	-.01646175
	13	-.00763535*	.000791075	.000	-.01279733	-.00247338
	14	-.19838831*	.000791075	0.000	-.20355028	-.19322633
	15	-.02754907*	.000791075	.000	-.03271104	-.02238709
	16	-.02540986*	.000791075	.000	-.03057184	-.02024789
	17	-.01671777*	.000791075	.000	-.02187974	-.01155579
	18	-.01598056*	.000791075	.000	-.02114253	-.01081858
	19	.00278843	.000791075	.997	-.00237355	.00795041
	20	-.01582370*	.000791075	.000	-.02098567	-.01066172
	21	-.02482986*	.000791075	.000	-.02999184	-.01966789
	22	.00829407*	.000791075	.000	.00313209	.01345604
	23	-.00983531*	.000791075	.000	-.01499729	-.00467334
	24	.01005486*	.000791075	.000	.00489289	.01521684
	25	-.01062362*	.000791075	.000	-.01578559	-.00546164
	26	-.00173736	.000791075	1.000	-.00689934	.00342462
	27	.00110592	.000791075	1.000	-.00405606	.00626790
	28	-.26180011*	.000791075	0.000	-.26696208	-.25663813
	29	-.11088237*	.000791075	0.000	-.11604435	-.10572040
	30	-.01275703*	.000791075	.000	-.01791901	-.00759505
10	11	-.01345242*	.000791075	.000	-.01861439	-.00829044
	12	-.00388628	.000791075	.722	-.00904826	.00127569
	13	.01010209*	.000791075	.000	.00494011	.01526407
	14	-.18065086*	.000791075	0.000	-.18581284	-.17548889
	15	-.00981162*	.000791075	.000	-.01497360	-.00464965
	16	-.00767242*	.000791075	.000	-.01283439	-.00251044
	17	.00101968	.000791075	1.000	-.00414230	.00618165
	18	.00175689	.000791075	1.000	-.00340509	.00691886
	19	.02052587*	.000791075	.000	.01536390	.02568785
	20	.00191375	.000791075	1.000	-.00324823	.00707572
	21	-.00709242*	.000791075	.000	-.01225439	-.00193044
	22	.02603151*	.000791075	.000	.02086954	.03119349
	23	.00790213*	.000791075	.000	.00274015	.01306411
	24	.02779231*	.000791075	.000	.02263033	.03295428
	25	.00711383*	.000791075	.000	.00195185	.01227580
	26	.01600008*	.000791075	.000	.01083811	.02116206
	27	.01884336*	.000791075	.000	.01368139	.02400534
	28	-.24406266*	.000791075	0.000	-.24922464	-.23890069
	29	-.09314493*	.000791075	0.000	-.09830690	-.08798295
	30	.00498041	.000791075	.090	-.00018156	.01014239

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
11	12	.00956613*	.000791075	.000	.00440416	.01472811
	13	.02355451*	.000791075	.000	.01839253	.02871648
	14	-.16719845*	.000791075	0.000	-.17236042	-.16203647
	15	.00364080	.000791075	.852	-.00152118	.00880277
	16	.00578000*	.000791075	.004	.00061802	.01094198
	17	.01447210*	.000791075	.000	.00931012	.01963407
	18	.01520931*	.000791075	.000	.01004733	.02037128
	19	.03397829*	.000791075	0.000	.02881632	.03914027
	20	.01536616*	.000791075	.000	.01020419	.02052814
	21	.00636000*	.000791075	.000	.00119802	.01152198
	22	.03948393*	.000791075	0.000	.03432195	.04464591
	23	.02135455*	.000791075	.000	.01619257	.02651652
	24	.04124473*	.000791075	0.000	.03608275	.04640670
	25	.02056625*	.000791075	.000	.01540427	.02572822
	26	.02945250*	.000791075	.000	.02429053	.03461448
	27	.03229578*	.000791075	0.000	.02713381	.03745776
	28	-.23061024*	.000791075	0.000	-.23577222	-.22544827
	29	-.07969251*	.000791075	0.000	-.08485449	-.07453053
	30	.01843283*	.000791075	.000	.01327086	.02359481
12	13	.01398837*	.000791075	.000	.00882640	.01915035
	14	-.17676458*	.000791075	0.000	-.18192656	-.17160260
	15	-.00592534*	.000791075	.002	-.01108731	-.00076336
	16	-.00378613	.000791075	.781	-.00894811	.00137584
	17	.00490596	.000791075	.113	-.00025601	.01006794
	18	.00564317*	.000791075	.007	.00048120	.01080515
	19	.02441216*	.000791075	.000	.01925018	.02957413
	20	.00580003*	.000791075	.003	.00063805	.01096201
	21	-.00320613	.000791075	.970	-.00836811	.00195584
	22	.02991780*	.000791075	.000	.02475582	.03507977
	23	.01178841*	.000791075	.000	.00662644	.01695039
	24	.03167859*	.000791075	.000	.02651662	.03684057
	25	.01100011*	.000791075	.000	.00583814	.01616209
	26	.01988637*	.000791075	.000	.01472439	.02504834
	27	.02272965*	.000791075	.000	.01756767	.02789162
	28	-.24017638*	.000791075	0.000	-.24533835	-.23501440
	29	-.08925864*	.000791075	0.000	-.09442062	-.08409667
	30	.00886670*	.000791075	.000	.00370472	.01402867

Table A3. Result of Randomized Completed Block Design (RCBD) for Area (Area)

Multiple Comparisons

Dependent Variable: Area

Scheffe

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
13	14	-.19075295*	.000791075	0.000	-.19591493	-.18559098
	15	-.01991371*	.000791075	.000	-.02507569	-.01475174
	16	-.01777451*	.000791075	.000	-.02293648	-.01261253
	17	-.00908241*	.000791075	.000	-.01424439	-.00392044
	18	-.00834520*	.000791075	.000	-.01350718	-.00318323
	19	.01042378*	.000791075	.000	.00526181	.01558576
	20	-.00818834*	.000791075	.000	-.01335032	-.00302637
	21	-.01719451*	.000791075	.000	-.02235648	-.01203253
	22	.01592942*	.000791075	.000	.01076745	.02109140
	23	-.00219996	.000791075	1.000	-.00736194	.00296202
	24	.01769022*	.000791075	.000	.01252824	.02285219
	25	-.00298826	.000791075	.990	-.00815024	.00217371
	26	.00589799*	.000791075	.002	.00073602	.01105997
	27	.00874127*	.000791075	.000	.00357930	.01390325
	28	-.25416475*	.000791075	0.000	-.25932673	-.24900278
	29	-.10324702*	.000791075	0.000	-.10840899	-.09808504
	30	-.00512168	.000791075	.057	-.01028365	.00004030
14	15	.17083924*	.000791075	0.000	.16567727	.17600122
	16	.17297845*	.000791075	0.000	.16781647	.17814042
	17	.18167054*	.000791075	0.000	.17650857	.18683252
	18	.18240775*	.000791075	0.000	.17724578	.18756973
	19	.20117674*	.000791075	0.000	.19601476	.20633871
	20	.18256461*	.000791075	0.000	.17740263	.18772659
	21	.17355845*	.000791075	0.000	.16839647	.17872042
	22	.20668238*	.000791075	0.000	.20152040	.21184435
	23	.18855299*	.000791075	0.000	.18339102	.19371497
	24	.20844317*	.000791075	0.000	.20328120	.21360515
	25	.18776469*	.000791075	0.000	.18260272	.19292667
	26	.19665095*	.000791075	0.000	.19148897	.20181292
	27	.19949423*	.000791075	0.000	.19433225	.20465620
	28	-.06341180*	.000791075	0.000	-.06857377	-.05824982
	29	.08750594*	.000791075	0.000	.08234396	.09266791
	30	.18563128*	.000791075	0.000	.18046930	.19079325
15	16	.00213920	.000791075	1.000	-.00302277	.00730118
	17	.01083130*	.000791075	.000	.00566932	.01599328
	18	.01156851*	.000791075	.000	.00640653	.01673049
	19	.03033750*	.000791075	.000	.02517552	.03549947
	20	.01172537*	.000791075	.000	.00656339	.01688734
	21	.00271920	.000791075	.998	-.00244277	.00788118
	22	.03584313*	.000791075	0.000	.03068116	.04100511
	23	.01771375*	.000791075	.000	.01255178	.02287573
	24	.03760393*	.000791075	0.000	.03244195	.04276591
	25	.01692545*	.000791075	.000	.01176347	.02208743
	26	.02581171*	.000791075	.000	.02064973	.03097368
	27	.02865499*	.000791075	.000	.02349301	.03381696
	28	-.23425104*	.000791075	0.000	-.23941302	-.22908906
	29	-.08333331*	.000791075	0.000	-.08849528	-.07817133
	30	.01479204*	.000791075	.000	.00963006	.01995401
16	17	.00869210*	.000791075	.000	.00353012	.01385407
	18	.00942931*	.000791075	.000	.00426733	.01459128
	19	.02819829*	.000791075	.000	.02303632	.03336027
	20	.00958616*	.000791075	.000	.00442419	.01474814
	21	.00058000	.000791075	1.000	-.00458198	.00574198
	22	.03370393*	.000791075	0.000	.02854195	.03886591
	23	.01557455*	.000791075	.000	.01041257	.02073652
	24	.03546473*	.000791075	0.000	.03030275	.04062670
	25	.01478625*	.000791075	.000	.00962427	.01994822
	26	.02367250*	.000791075	.000	.01851053	.02883448
	27	.02651578*	.000791075	.000	.02135381	.03167776
	28	-.23639024*	.000791075	0.000	-.24155222	-.23122827
	29	-.08547251*	.000791075	0.000	-.09063449	-.08031053
	30	.01265283*	.000791075	.000	.00749086	.01781481
17	18	.00073721	.000791075	1.000	-.00442477	.00589919
	19	.01950620*	.000791075	.000	.01434422	.02466817
	20	.00089407	.000791075	1.000	-.00426791	.00605604
	21	-.00811210*	.000791075	.000	-.01327407	-.00295012
	22	.02501183*	.000791075	.000	.01984986	.03017381
	23	.00688245*	.000791075	.000	.00172048	.01204443
	24	.02677263*	.000791075	.000	.02161065	.03193461
	25	.00609415*	.000791075	.001	.00093217	.01125613
	26	.01498041*	.000791075	.000	.00981843	.02014238
	27	.01782369*	.000791075	.000	.01266171	.02298566
	28	-.24508234*	.000791075	0.000	-.25024432	-.23992036
	29	-.09416461*	.000791075	0.000	-.09932658	-.08900263
	30	.00396074	.000791075	.675	-.00120124	.00912271
18	19	.01876899*	.000791075	.000	.01360701	.02393096
	20	.00015686	.000791075	1.000	-.00500512	.00531883
	21	-.00884931*	.000791075	.000	-.01401128	-.00368733
	22	.02427462*	.000791075	.000	.01911265	.02943660
	23	.00614524*	.000791075	.001	.00098327	.01130722
	24	.02603542*	.000791075	.000	.02087344	.03119740
	25	.00535694*	.000791075	.024	.00019496	.01051892
	26	.01424320*	.000791075	.000	.00908122	.01940517
	27	.01708648*	.000791075	.000	.01192450	.02224845
	28	-.24581955*	.000791075	0.000	-.25098153	-.24065757
	29	-.09490182*	.000791075	0.000	-.10006379	-.08973984
	30	.00322353	.000791075	.968	-.00193845	.00838550
19	20	-.01861213*	.000791075	.000	-.02377410	-.01345015
	21	-.02761829*	.000791075	.000	-.03278027	-.02245632
	22	.00550564*	.000791075	.013	.00034366	.01066761
	23	-.01262374*	.000791075	.000	-.01778572	-.00746177
	24	.00726643*	.000791075	.000	.00210446	.01242841
	25	-.01341205*	.000791075	.000	-.01857402	-.00825007
	26	-.00452579	.000791075	.289	-.00968777	.00063619
	27	-.00168251	.000791075	1.000	-.00684449	.00347947
	28	-.26458854*	.000791075	0.000	-.26975051	-.25942656
	29	-.11367080*	.000791075	0.000	-.11883278	-.10850883
	30	-.01554546*	.000791075	.000	-.02070744	-.01038348

Table A3. Result of Randomized Completed Block Design (RCBD) for Area (Area)

Multiple Comparisons

Dependent Variable: Area

Scheffe

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
20	21	-.00900616*	.000791075	.000	-.01416814	-.00384419
	22	.02411777*	.000791075	.000	.01895579	.02927974
	23	.00598838*	.000791075	.001	.00082641	.01115036
	24	.02587856*	.000791075	.000	.02071659	.03104054
	25	.00520008*	.000791075	.044	.00003811	.01036206
	26	.01408634*	.000791075	.000	.00892436	.01924831
	27	.01692962*	.000791075	.000	.01176764	.02209159
	28	-.24597641*	.000791075	0.000	-.25113838	-.24081443
	29	-.09505867*	.000791075	0.000	-.10022065	-.08989670
	30	.00306667	.000791075	.985	-.00209531	.00822864
21	22	.03312393*	.000791075	0.000	.02796195	.03828591
	23	.01499455*	.000791075	.000	.00983257	.02015652
	24	.03488473*	.000791075	0.000	.02972275	.04004670
	25	.01420625*	.000791075	.000	.00904427	.01936822
	26	.02309250*	.000791075	.000	.01793053	.02825448
	27	.02593578*	.000791075	.000	.02077381	.03109776
	28	-.23697024*	.000791075	0.000	-.24213222	-.23180827
	29	-.08605251*	.000791075	0.000	-.09121449	-.08089053
	30	.01207283*	.000791075	.000	.00691086	.01723481
22	23	-.01812938*	.000791075	.000	-.02329136	-.01296741
	24	.00176080	.000791075	1.000	-.00340118	.00692277
	25	-.01891768*	.000791075	.000	-.02407966	-.01375571
	26	-.01003143*	.000791075	.000	-.01519340	-.00486945
	27	-.00718815*	.000791075	.000	-.01235012	-.00202617
	28	-.27009417*	.000791075	0.000	-.27525615	-.26493220
	29	-.11917644*	.000791075	0.000	-.12433842	-.11401446
	30	-.02105110*	.000791075	.000	-.02621307	-.01588912
23	24	.01989018*	.000791075	.000	.01472820	.02505215
	25	-.00078830	.000791075	1.000	-.00595028	.00437367
	26	.00809795*	.000791075	.000	.00293598	.01325993
	27	.01094123*	.000791075	.000	.00577926	.01610321
	28	-.25196479*	.000791075	0.000	-.25712677	-.24680282
	29	-.10104706*	.000791075	0.000	-.10620903	-.09588508
	30	-.00292172	.000791075	.993	-.00808369	.00224026
24	25	-.02067848*	.000791075	.000	-.02584046	-.01551650
	26	-.01179222*	.000791075	.000	-.01695420	-.00663025
	27	-.00894894*	.000791075	.000	-.01411092	-.00378697
	28	-.27185497*	.000791075	0.000	-.27701695	-.26669299
	29	-.12093724*	.000791075	0.000	-.12609921	-.11577526
	30	-.02281189*	.000791075	.000	-.02797387	-.01764992
25	26	.00888626*	.000791075	.000	.00372428	.01404823
	27	.01172954*	.000791075	.000	.00656756	.01689151
	28	-.25117649*	.000791075	0.000	-.25633847	-.24601451
	29	-.10025876*	.000791075	0.000	-.10542073	-.09509678
	30	-.00213341	.000791075	1.000	-.00729539	.00302856
26	27	.00284328	.000791075	.996	-.00231870	.00800526
	28	-.26006275*	.000791075	0.000	-.26522472	-.25490077
	29	-.10914501*	.000791075	0.000	-.11430699	-.10398304
	30	-.01101967*	.000791075	.000	-.01618165	-.00585769
27	28	-.26290603*	.000791075	0.000	-.26806800	-.25774405
	29	-.11198829*	.000791075	0.000	-.11715027	-.10682632
	30	-.01386295*	.000791075	.000	-.01902493	-.00870097
28	29	.15091773*	.000791075	0.000	.14575576	.15607971
	30	.24904308*	.000791075	0.000	.24388110	.25420505
29	30	.09812534*	.000791075	0.000	.09296337	.10328732

VITA

NAME	Nareerat Benjapatanamongkol
PLACE OF BIRTH	Bangkok
INSTITUTIONS ATTENDED	Thammasat University, University of Nottingham, Assumption University
PUBLICATION	A Preliminary Study on Finger Area and Keystroke Dynamics Using Touchscreen Smartphones with Random Numeric Keypad