Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X
IMPACT FACTOR: 7.056

IJCSMC, Vol. 15, Issue. 1, January 2026, pg.81 – 118

Statistical Comparison of Manual and Machine Learning Signature Verification Using Neural Networks on Raspberry Pi

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DOI: https://doi.org/10.47760/ijcsmc.2026.v15i01.008

ABSTRACT: This study presents a statistical comparison between a machine learning-based handwritten signature verification system, and a traditional manual verification method. The research aims to compare and evaluate signatures by applying machine learning and image processing techniques. It integrates a Raspberry Pi 3 Model B+ with a camera module and a touchscreen interface to capture and process handwritten signatures. Three neural network algorithms—LeNet, Feed Forward, and VGG16 Transfer Learning—were trained and tested using a dataset of 4,668 genuine and forged signature samples. Image pre-processing techniques such as grayscale conversion, thresholding, and noise reduction were employed to enhance data quality. Among the three algorithms, the LeNet model achieved the highest accuracy of 99.36%, outperforming the Feed Forward (99.20%) and VGG16 Transfer Learning (99.14%) models. Using the LeNet model, a comparative assessment was conducted between the manual verification method and the machine learning-based verification system. The Mann-Whitney U test confirmed that the verification system showed significantly higher accuracy and reliability in verifying genuine and forged signatures. The null hypothesis—that there is no difference between the manual and system methods—was rejected at a significance level of 0.05. Furthermore, system acceptability was assessed through a survey conducted among technical experts, focusing on usability, convenience, interface design, and output accuracy. The survey demonstrated acceptable reliability (Cronbach's alpha = 0.728) and produced a grand mean score of 4.6 out of 5, indicating a "Very Good" perception of the system's performance and user-friendliness.

KEYWORDS: Neural Network, Image Processing, Raspberry Pi, Signature Verification, Machine Learning

I. INTRODUCTION

Verifying handwritten signatures is a key way to confirm a person's identity. Signatures are used in many important areas like banks, legal documents, schools, and businesses. Checking if a signature is authentic helps prevents fraud and protect people's information. Traditional manual signature verification is time-consuming and prone to inaccuracies as it depends on human evaluation and judgment. To improve the efficiency and precision of signature verification, intelligent computer-based systems have been developed using machine learning and image processing techniques. The Raspberry Pi is a small and affordable microcomputer ideal for building such systems. It works well with image processing tools like OpenCV and programming languages like Python. This research developed a system that uses the Raspberry Pi and machine learning to check if a signature is genuine or forged. The system uses a camera to take pictures of signatures and displays the results on a LCD screen. It uses neural network models, which are computational framework that learn from many examples. Three neural network models were tested to see which works best. The model with the highest accuracy was chosen to run on the Raspberry Pi. The system is designed to be low-cost, easy to use, and portable, making it useful for many places that need quick and reliable signature checks.

This research aims to provide a statistical comparison between a machine learning-based handwritten signature verification system using Neural Network by utilizing Raspberry Pi and a traditional manual verification method. The objectives are to (1)Develop a system that captures and processes handwritten signatures using Raspberry Pi (2)Train and test three neural network models: LeNet, Feed Forward, and VGG16 Transfer Learning for signature verification (3)Compare the models by accuracy and (model loss)error (4) Compare the results of manual signature verification with the machine learning-based verification system.

II. OBJECTIVES OF THE STUDY

The main objectives of this research is to develop, train, test and evaluate a machine learning-based handwritten signature verification system and provide a statistical comparison to manual signature verification method.

Specifically, the study aims to:

1. To develop a system that captures and processes handwritten signatures using Raspberry Pi hardware.
2. To train and test three Neural Network models—LeNet, Feed Forward, and VGG16 Transfer Learning—for signature verification.
3. To analyze model performance in terms of Model accuracy and Model loss.
4. To compare the manual method in verifying hand written signatures with the proposed algorithm.

III. METHODOLOGY

A. Research Design

This study employed a developmental, experimental and statistical research design to provide a statistical comparison between a Machine Learning-Based Handwritten Signature Verification System using Raspberry Pi and traditional manual verification method. The performance of three Neural Network algorithms—LeNet, Feed Forward Neural Network, and VGG16 Transfer Learning was evaluated, with LeNet ultimately selected based on its higher accuracy (99.36%) and minimal model loss (1.4%).

B. Data Collection Procedure

1. Signature Data Gathering – Genuine and forged signature samples were collected from the three researchers. Image pre-processing techniques were applied before dataset generation.
2. Model Training and Validation – The neural network models (LeNet, Feed Forward, and VGG16) were trained using 3,668 samples for training and 933 samples for validation. Each model required approximately 2–3 hours of training time.

3. System Evaluation – After selecting the best-performing neural network model (LeNet), the system was assembled and tested in a controlled setting using the researchers' signature datasets.
4. Survey Administration – The acceptability survey was conducted among 73 technical respondents through two modes:
   - Face-to-Face Evaluation: Respondents interacted directly with the device.
   - Online Evaluation: Respondents completed the survey via Google Forms after viewing a demonstration video of the system.
5. Data Compilation and Tabulation – Collected data were tabulated, averaged, and interpreted using descriptive statistical methods.

C. Sampling

The study used purposive sampling for data acquisition and evaluation. The signature dataset consisted of handwritten samples from three (3) researchers, divided into two categories: genuine and forged. A total of 4,668 samples were collected, comprising 3,098 genuine and 1,570 forged signatures.

Genuine signature sample Person X

A total of 1,017 of genuine was collected from Person X

Fig. 1 Genuine Signature samples of Person X

Genuine signature sample Person Y

A total of 1,029 of genuine was collected from Person Y.

Fig. 2 Genuine Signature samples of Person Y

Genuine signature sample Person Z
A total of 1,052 of genuine was collected from Person Y.

Fig. 3 Genuine Signature samples of Person Z

Genuine Signature Samples	
Signature Samples	No. of Samples
Person X	1,017
Person Y	1,029
Person Z	1,052
Total	3,098

Table 1. Total Number of Genuine Signature Samples

Forge Signature Samples				
Signature Samples	Person X (548)	Person Y (443)	Person Z (579)	
Person X		266	282	
Person Y	218		225	
Person Z	298	281		
Total	516	547	507	1,570

Table 2. Total Number of Forge Signature samples

D. Instruments and Measures

1. Software Components

a) Google Colaboratory - Google Colaboratory was used to run accuracy testing procedures, compute performance metrics, and record model training logs. It ensured consistent environment settings during model evaluation.

b) Python Programming Language - Python's built-in and library-supported functions (NumPy, scikit-learn, Matplotlib) were used to compute quantitative evaluation metrics, conduct statistical analysis, generate confusion matrices, and visualize model performance curves.

c) TensorFlow - TensorFlow generated quantitative performance outputs such as training/validation accuracy, loss values, precision, recall, and F1-scores, which formed the basis for evaluating the model's effectiveness.

2. Survey Instrument Acceptability Evaluation

A technical evaluation sheet was developed by the researchers that fit the requirements of the study. It was subjected to validity and reliability process. Five (5) technical experts validated the survey questionnaire to ensure that it measured what it intended to measure. The survey questionnaire was subjected to the Good and Scates Validity Test, wherein it was presented to the technical experts in the field of programming and machine learning. Each item of the survey

questionnaire was given an affirmative scale of 1 to 5 with adjectival interpretation as a guideline for tabulating and interpreting assessment performance.

RATING	VERBAL INTERPRETATION
1	Strongly Disagree
2	Disagree
3	Undecided
4	Agree
5	Strongly Agree

Table.3 Good and Scates criterion for validation

In determining the grand mean, each mean score was interpreted using the following scale rating based on the evaluation sheet for the performance of the Good and Scates.

Mean = Sum of Respondents' scores on a criterion / total number of respondents

Grand mean = Sum of the means / total number of question items

The mean score and grand mean of the evaluation procedure was interpreted using the scale in Table 4.

Rating	Verbal Interpretation
4.50 -5.00	Very Good
3.50-4.49	Good
2.50-3.49	Average
1.50-2.49	Poor
1.00-1.49	Very Poor

Table. 4 Good and Scates Scale Used to Rate Each Criterion and Grand mean

3. Survey Instrument Reliability Evaluation

The results were then compared and interpreted using Cronbach's Alpha developed by Lee Cronbach (1951). This was believed to measure the consistency of the result on the responses of the survey questionnaire. The responses of the respondents were subjected to reliability testing using Cronbach's Alpha. Computation for System Reliability Evaluation Procedure is shown in Figure 4.

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$$

Figure. 4 Cronbach's Alpha Formula

Where:

N = the number of items,

$\bar{c}$ = average covariance between item-pairs.

$\bar{v}$ = average variance.

The Cronbach's alpha value was interpreted using Cronbach's Alpha level of reliability shown in Table 5

Cronbach's Alpha Reliability Level	
> 0.90	Excellent
0.80 – 0.89	Good
0.70 – 0.79	Acceptable
0.60 – 0.69	Questionable
0.50 – 0.59	Poor
< 0.50	Unacceptable

Table.5 Cronbach's Alpha level of reliability

A Cronbach's Alpha value of 0.728 and above indicated that the instrument had acceptable reliability and consistency across all test items.

4. System Acceptability Evaluation

For the system acceptability, the researchers targeted technical professionals from the Information and Communication, Financial and Insurance Activities sectors in Bacolod City based on the statistics of the Philippine Statistics Authority. Using the Cochran and Modified Cochran formulas, the computed representative sample size was seventy-three (73) respondents. In addition, thirty (30) technical respondents participated in the reliability testing of the survey instrument. Respondents were selected based on their technical expertise and experience in signature authentication systems.

PHILIPPINES/ REGION/ PROVINCE	Total Employed Population (in '000) Annual 2021			Employment Rate (%) Annual 2021		
	Estimate ('000)	Standard Error ('000)	Coefficient of Variation (%)	Estimate (%)	Standard Error (%)	Coefficient of Variation (%)
REGION VI (WESTERN VISAYAS)	**3,256**	**52**	**2**	**93**	**0**	**0**
Aklan	238	8	3	89	0	0
Antique	252	8	3	94	0	0
Capiz	360	13	4	95	0	0
Iloilo	818	24	3	93	0	0
Iloilo City	181	6	4	89	0	0
Negros Occidental	1,080	43	4	95	0	0
Bacolod City	255	8	3	93	0	0
Guimaras	72	3	5	96	0	0

Note: Details may not add up to totals due to rounding.

All estimates used the 2015 POPCEN-based Population Projection.

Source: Philippine Statistics Authority, 2021 Labor Force Survey

Fig. 4 Annex For Target Population Data in Bacolod City (PSA, 2021)

Major Industry Group	Estimate		Standard Error	
	July 2020	July 2021	July 2020	July 2021
Philippines Number (in thousands)	41,302	41,671	549	273.0
Total	100.0	100.0		
Agriculture	26.3	22.0	0.6	0.3
Agriculture and forestry	23.6	19.2	0.6	0.3
Fishing and aquaculture	2.7	2.9	0.2	0.1
Industry	18.8	19.9	0.4	0.2
Mining and quarrying	0.6	0.5	0.1	0.0
Manufacturing	8.2	8.5	0.3	0.1
Electricity, gas, steam, and air conditioning supply	0.2	0.2	0.0	0.0
Water supply; sewerage, waste management and remediation activities	0.1	0.2	0.0	0.0
Construction	9.8	10.5	0.2	0.1
Services	54.8	58.1	0.5	0.3
Wholesale and retail trade; repair of motor vehicles and motorcycles	21.5	20.5	0.3	0.1
Transportation and storage	7.1	7.1	0.2	0.1
Accommodation and food service activities	3.1	3.4	0.1	0.1
Information and communication	0.7	1.1	0.1	0.0
Financial and insurance activities	1.4	1.5	0.1	0.0
Real estate activities	0.5	0.5	0.0	0.0
Professional, scientific and technical activities	0.6	1.0	0.1	0.0
Administrative and support service activities	3.7	4.9	0.1	0.1
Public administration and defense; compulsory socia	6.2	6.4	0.2	0.1
Education	2.9	3.3	0.1	0.1
Human health and social work activities	1.3	1.6	0.1	0.0
Arts, entertainment, and recreation	0.3	0.8	0.0	0.0
Other service activities	5.5	6.0	0.1	0.1
Activities of extraterritorial organizations and bodies	0.0	0.0	0.0	0.0

Note: 0.0 - less than 0.05 percent
0.0 does not imply absence of observation for the indicator, instead it implies very low observation
All estimates used the 2015 POPCEN-based Population Projection.
Source: Philippine Statistics Authority, *July 2020 and 2021 Labor Force Survey*

Fig. 5 Percent Distribution of Employed Persons (PSA, 2021)

As observed in the figure above, the identified employed population rate in Bacolod City as of 2021 is 255,000 people. The percent distribution employed in the industry of "Information and Communication" and "Financial and Insurance Activities" highlighted in Figure 5 is 0.7% and 1.4%. These percentages were added up, resulting in 2.1% as the respondents focused on these industries.

Target Population Computation

$$n_o = \frac{z_{\frac{\alpha}{2}}^2 pq}{e^2}$$

Fig. 6 Cochran formula

Where: z α/2 = alpha level's z-score.
e = is the desired level of precision.
p = is the (estimated) proportion of the population which has the attribute in question.
q = is 1 – p.

The computation for Cochran formula is shown in figure below:

Where:

$$z\ \alpha/2 = 1.96; \qquad e = 0.05; \qquad p = 0.95; \qquad q = 0.05$$

$$n_o = \frac{z_{\frac{\alpha}{2}}^2 pq}{e^2} = \frac{(1.96)^2(0.95)(0.05)}{(0.05)^2} = \mathbf{73}$$

Fig. 7 Sample size Cochran Formula

The Modified Cochran formula is an adjusted sample size derived from Cochran's sample size recommendation for small populations (Glenn, 2022). The Modified Cochran formula was used to adjust the sample size of respondents in Bacolod to achieve substantially smaller sample size in the study. Computation for Cochran formula sample size is shown in

$$n = \frac{n_0}{1 + \left(\frac{n_0 - 1}{N}\right)}$$

Fig. 8 Modified Cochran Formula

The computation for Cochran formula is shown in figure below:

$$n = \frac{n_0}{1 + \left(\frac{n_0 - 1}{N}\right)} = \frac{73}{1 + \left(\frac{z^2 p(1-p)}{e^2 N}\right)} = \frac{73}{1 + \frac{(1.96^2 \times 0.95 \times 0.05)}{0.05^2 \times 5{,}355}} = 72.7 \approx \mathbf{73}$$

Fig. 9 Sample Size Modified Cochran Formula

A survey is performed to determine the system acceptability using quantitative analysis. A panel of thirty (30) for the reliability test and seventy-three (73) technical respondents for the actual survey was distributed with a survey questionnaire. The selection of respondents was limited to technical experts with a signature authentication background of work.

The survey was evaluated in 2 options: (1) Face to face and (2) Online. The printed survey questionnaire was gathered in the face-to-face evaluation, and the researchers demonstrated how to use the device. In the online evaluation, the researchers used Google Forms to collect the responses of the respondents. A video was linked in the Google Forms for the respondents to evaluate the device by watching the demonstration of using the device and its functions. A score system was used in which each region was scored as one (1) to five (5), with one being the lowest and five being the highest. The results obtained from the respondents was collected, measured and statistically processed. The mean for each computation, a grand mean was acquired to verify the overall result for a specific area of assessment.

Rating	Verbal Interpretation
1	Very Poor
2	Good
3	Average
4	Good
5	Very Good

Table. 6 Survey Questionnaire Criterion

In determining the grand mean, each mean score was interpreted using the following scale rating based on the evaluation sheet for the performance of the Good and Scates.

Mean = Sum of Respondents' scores on a criterion / total number of respondents

Grand mean = Sum of the means / total number of respondents

The mean score and grand mean score of the evaluation procedure was interpreted using the scale in the table 7.

Rating	Verbal Interpretation
4.21-5.00	Very Good
3.41-4.20	Good
2.61-3.40	Average
1.81-2.60	Poor
1.00-1.80	Very Poor

Table. 7 Survey Questionnaire Scale Used to Rate Each Criterion and for Overall Score

4. System Accuracy Evaluation

The accuracy of the system refers to the degree to which the system verifies the signature being conducted in terms of genuine and forged. The device was checked for the recorded result and was compared to the actual genuine and forge samples. The evaluation consisted of thirty (30) trials, that was consolidated and used for the computation of percent error (%error) as a measure of accuracy, indicated in Figure 10.

Signature detection and verification evaluation (%error)

$$= \frac{\Sigma(System\ recorded\ signature - Actual\ signature\ recieved}{Actual\ signature\ received}$$

Fig. 10 System Accuracy evaluation formula

5. Comparative Analysis

This was evaluated by comparing the manual method of detecting and verifying handwritten signatures. The proponents prepared a test questionnaire that consisted of thirty (30) items. The questionnaire consisted of three (3) genuine samples of each person as a basis for the respondents. Each number consisted of two images and the respondents had to select between the two, choice A and choice B, which is the forged signature.

The evaluation procedure was tested using the Mann-Whitney U Test in IBM SPSS software. This nonparametric test assessed whether significant differences existed between manual and system-based verification accuracy levels.

The null and alternative hypotheses were:

H_0: *There is no significant difference between the accuracy level of manual and system-generated verification method.*

H_0: *There is a significant difference between the accuracy level of manual and system-generated verification method.*

Null Hypothesis and Alternative Hypothesis
A significance level (p-value) of 0.001 was used as the decision threshold.
If $p < 0.001$, **reject H_0**.
If $p > 0.001$, **fail to reject H_0**.
Decision Rule

5. Ethical Consideration

The study adhered to ethical standards in data collection and participant involvement. All participants were informed of the study's purpose, the use of their handwritten signatures solely for research purposes, and their right to withdraw at any time. Data privacy and confidentiality were strictly maintained. For survey respondents, informed consent was obtained prior to participation, ensuring voluntary and anonymous responses. No personal identifiers were included in the data analysis or reporting.

IV. RESULTS AND DISCUSSION

In this chapter, the results are presented and discussed regarding the aim of the study, which was the developmental, experimental and statistical research design to provide a statistical comparison between a Machine Learning-Based Handwritten Signature Verification System using Raspberry Pi and traditional manual verification method. This chapter includes the reviews of the results and analysis of the qualitative data, the compilation of the questionnaire and the results and analysis of the findings of the study.

The researchers were able to train and evaluate the model accuracy and model loss of the three (3) Neural Network algorithms: the LeNet, Feed forward and the VGG16 Transfer Learning. The LeNet algorithm was used for its high accuracy percentage and low loss percentage. Out of the three (3) algorithms, the LeNet had the highest model accuracy reaching a 99.36% accuracy and having a loss of 1.4% as shown in Table 12. The training time duration for each model varied from 2 to 3 hours using all training and validation samples for the research.

Model Accuracy Comparison

Neural Network Algorithm	Model Accuracy	Model Loss
LeNet Algorithm	99.36%	1.4%
Feed Forward Algorithm	99.20%	1.56%
VGG 16 Transfer Learning	99.14%	2.12%

Table. 8 Summary of Accuracy and Loss Metrics of the Three Neural Network Algorithms

1. LeNet Algorithm Results

The model was implemented with an image size 180 x 180. The model was trained initially with 4668 images for 15 epochs. After the 15 epochs, the training accuracy reached 99.14% and validation accuracy 97.96% as seen in Figure 11. Training loss reached 1.9% and the validation loss varied wildly but ended on 5.8% as seen in Figure 12. The model accuracy reached 99.36% having model loss reached 1.4%.

Lenet Model Training Result

```
- 111s 2s/step - loss: 0.0195 - accuracy: 0.9914 - val_loss: 0.0586 - val_accuracy: 0.9796
```

LeNet Training and Validation Visualization

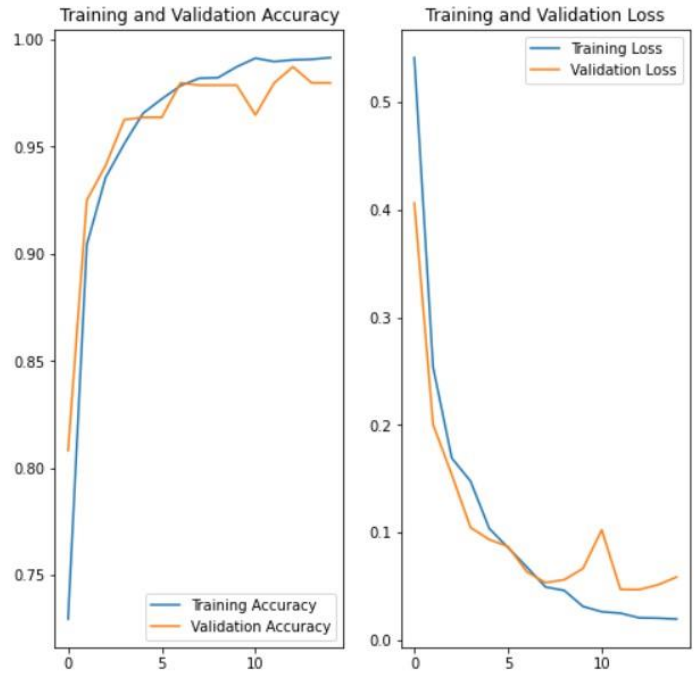

Fig. 11 LeNet Training and Validation Visualization

```
[ ]  #EVALUATE THE MODEL
     loss, acc = model.evaluate(train_ds, verbose=2)
     print("Model accuracy: {:5.2f}%".format(100 * acc))

     59/59 - 28s - loss: 0.0140 - accuracy: 0.9936 - 28s/epoch - 478ms/step
     Model accuracy: 99.36%
```

Fig. 12 LeNet Model Accuracy and Model Loss

2. Feed forward

The model was implemented with an image size 180 x 180. The model was trained initially with 4668 images for 15 epochs. After the 15 epochs, the training accuracy reached 98.29% and validation accuracy 95.61% as seen in Figure 13. Training loss reached 4% and the validation loss varied wildly but ended on 1.8% as seen in Figure 15. The model accuracy reached 99.20% having model loss reached 1.56%.

```
· loss: 0.0408 - accuracy: 0.9829 - val_loss: 0.1842 - val_accuracy: 0.9561
```

Fig. 13 Feed forward Training and Validation Result

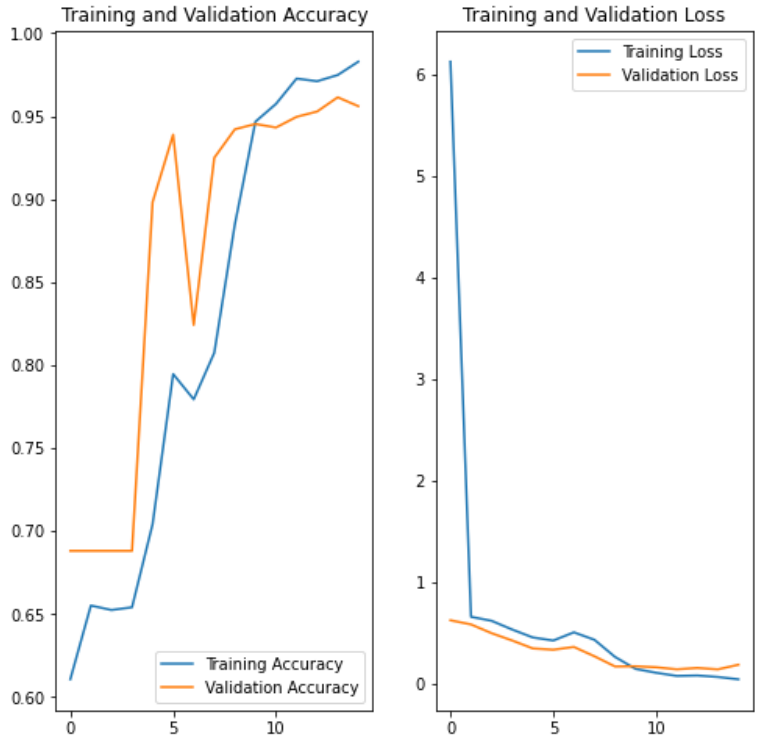

Fig. 14 Feed forward Training and Validation Visualization

```
[ ]  #EVALUATE THE MODEL
     loss, acc = model.evaluate(train_ds, verbose=2)
     print("Model accuracy: {:5.2f}%".format(100 * acc))

     117/117 - 64s - loss: 0.0156 - accuracy: 0.9920 - 64s/epoch - 543ms/step
     Model accuracy: 99.20%
```

Fig. 15 Feed forward Model Accuracy and Model Loss

3. VGG16 Transfer Learning

The model was implemented with an image size 192 x 192. The model was trained initially with 4668 images for 15 epochs. In the first training, after the 10 epochs, the training accuracy reached 99.14% and validation accuracy 99.14% as seen in Figure 16. Training loss reached 2.2% and the validation loss varied wildly but ended on 2.1% as seen in Figure 18. The model accuracy reached 99.14% having model loss reached 2.12%.

```
- 152s 3s/step - loss: 0.0229 - accuracy: 0.9914 - val_loss: 0.0212 - val_accuracy: 0.9914
```

Fig. 16 VGG16 Transfer Learning 1st Training and Validation Result

In the second training, after the 10 epochs, the training accuracy reached 93.65% and validation accuracy 96.78% as seen in Figure 17. Training loss reached 2.3% and the validation loss varied wildly but ended on 1.9% as seen in Figure 17.

```
· 89s 2s/step - loss: 0.2348 - accuracy: 0.9365 - val_loss: 0.1991 - val_accuracy: 0.9678
```

Fig. 17 VGG16 Transfer Learning 2nd Training and Validation Result


```
[ ]  loss, accuracy = model.evaluate(val_ds)
     print("Model accuracy: {:5.2f}%".format(100 * accuracy))

     15/15 [==============================] - 19s 1s/step - loss: 0.0212 - accuracy: 0.9914
     Model accuracy: 99.14%
```

Fig. 18 VGG16 Transfer Learning Model Accuracy and Model Loss

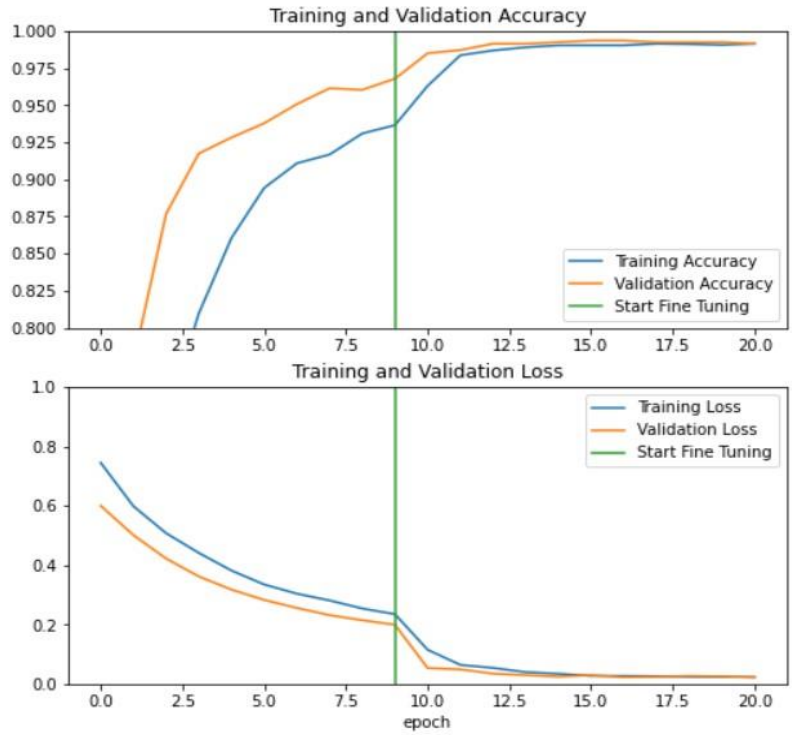

Fig. 19 VGG16 Transfer Learning Training and Validation Visualization

A. Survey Acceptability Evaluation

The proponents were able to evaluate the design project by conducting a survey of respondents after the design project was oriented and the prototype itself was tested. The five technical experts were given a survey questionnaire through Google Forms to validate the self-made questionnaire and were also asked to give comments and recommendations. The respondents were given an evaluation sheet to validate the self-made questionnaire. Each criterion was ranked from one to five, with five as the highest. provides summary of the results of the survey given to the five technical experts.

Indicator	Mean Score	Verbal Interpretation
1. The items in the instrument are relevant to answer the objectives of the study.	5.0	Very Good
2. The items in the instrument can obtain depth to constructs being measured.	4.8	Very Good
3. The instrument has an appropriate sample of items for the construct being measured	4.8	Very Good
4. The items and their alternatives are neither too narrow nor limited in its content.	4.6	Very Good
5. The items in the instrument are stated clearly.	5.0	Very Good
6. The items on the instrument can elicit responses which are stable, definite, consistent and not conflicting.	4.8	Very Good

7. The terms adapted in the scale in the scale are culturally appropriate.	4.8	Very Good
8. The layout or format of the instrument is technically sound.	4.8	Very Good
9. The responses on the scale show a reasonable range of variation.	5.0	Very Good
10. The instrument is not too short or long enough that the participants will be able to answer it within a given time.	5.0	Very Good
11. The instrument is interesting such that participants will be induced to respond to it and accomplish it fully.	5.0	Very Good
12. The instrument as a whole could answer the basic purpose for which it is designed.	5.0	Very Good
13. The instrument is culturally acceptable when administered in the local setting.	4.8	Very Good
GRAND MEAN	4.8	Very Good

Table. 9 Survey Results for the System Acceptability Evaluation

$$\text{Grand Mean} = \frac{63.4}{13}$$

Grand Mean = 4.8

The respondent's ratings were added for each criterion and the average was calculated. The overall survey questionnaire was therefore interpreted as "Very Good" for the assessment.

B. Survey Instrument Reliability Evaluation

Category	Cronbach's Alpha Value	Number of Statements	Level of Reliability
Degree of Compliance	0.728	10	Acceptable

Table. 10 System Reliability Evaluation Score

The results from the thirty respondents were interpreted and compared using Cronbach's alpha. Table 10 shows the results of the reliability tests conducted for the questionnaire with Cronbach's Alpha Value of 0.728 for the evaluation of the degree of compliance of the system for the survey questionnaire. This value indicates a good level of internal consistency for reliability, or as interpreted by Mohd Arof, Khairul & Ismail, Syuhaida & Saleh, Abd Latif which is at "acceptable" level of reliability.

C. Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Number of Items
.728	.733	10

Table. 11 Reliability Statistics

Further analysis on the item-total statistics shown in the Table 12, the removal of statement 1, 2, and 6 would result in a slightly higher Cronbach's alpha based on the Cronbach's Alpha Based on Standardized items in Table 11. However though, the difference might be negligible. Thus, the researchers considered to retain the questionnaire as it is and proceeded with the data gathering.

	Scale mean if item deleted	Scale Variance if item deleted	Corrected Item-total correlation	Squared multiple correlaton	Cronbach's alpha if item deleted
1. Verification of signatures are faster than the conventional or manual method.	43.43	4.392	.129	.655	.734
2. The device is easy to use and is convenient.	43.57	4.254	4.254	.408	.751
3. The User Interface (UI) of the device is user-friendly	43.67	3.540	3.540	.424	.716
4. The prototype device is presentable and aesthetically acceptable.	43.53	3.982	3.982	.577	.718
5. Processing inputs to the device is easy and convenient.	43.57	3.220	3.220	.694	.655
6. The assistance of a technical person is required to use this system.	43.63	3.826	3.826	.359	.741
7. The instruction provided with the system is clear and easy to understand.	43.53	3.775	3.775	.626	.696
8. The information outputs of the system is meaningful and appropriate.	43.53	3.706	3.706	.458	.688
9. Signature verification results of the system is accurate.	43.60	3.490	3.490	.577	.676
10. The overall rating for the verification system.	43.53	3.568	3.568	.710	.671

Table. 12 Item-Total Statistics

D. System Acceptability Evaluation

Indicator	Mean Score	Verbal Interpretation
1. Detection and verification of signatures are faster than the conventional or manual method.	4.7	Very Good
2. The device is easy to use and is convenient.	4.7	Very Good
3. The User Interface (UI) of the device is user-friendly.	4.8	Very Good
4. The prototype device is presentable and aesthetically acceptable.	4.6	Very Good
5. Processing inputs to the device is easy and convenient.	4.7	Very Good
6. The assistance of a technical person is required to use this system.	4.5	Very Good
7. The instruction provided with the system is clear and easy to understand.	4.8	Very Good
8. The information outputs of the system is meaningful and appropriate.	4.7	Very Good
9. Signature verification and detection results of the system is accurate.	4.6	Very Good
10. The overall rating for the detection and verification system.	4.8	Very Good
GRAND MEAN	4.6	Very Good

Table. 13 Technical Survey Results for the System Acceptability Evaluation Procedure

$$\text{Grand Mean} = \frac{46.794}{10}$$

$$\text{Grand Mean} = 4.6$$

The respondent's ratings were added for each criterion and the average was calculated. The overall system was therefore interpreted as "Very Good" for the System Acceptability Evaluation of the technical respondents.

Table 13 showed the system to be very good in terms of features and making the system easy to run, simple and user-friendly. The system was good in terms of efficiency, which helped the system to do the job with the least time and effort. As far as the placing inputs is concerned, the processing of inputs was easy and convenient. A very good note was that the project design is a helpful development. With regards to result of the system output, the respondents rated the system with a very good remark, that showed how accurate the system was. The overall rating for the Machine Learning-Based Handwritten Signature Verification System made an excellent remark that the system design performed satisfactorily.

The result revealed that design was very good with a grand mean of 4.6 which was the sum of the individual means of the different criteria, divided by the number of criteria for the evaluation.

System Accuracy Evaluation

The proponents were able to evaluate the Machine Learning-Based Handwritten Signature Verification System in terms of the number of successful readings. The system was evaluated by doing an actual test and comparing the input handwritten signature scanned on the device to the result that was displayed on the TFT LCD Touchscreen. The error percentage is computed using the formula indicated on Figure 10 in the previous chapter.

Legend: ✓ = Correct or successful result – Matched Reading

X = Incorrect or failed result – Not Matched Reading

PERSON X			
TRIAL	**AUTHENTICITY**	**ACCURACY(%)**	**% ERROR**
GENUINE TEST			
1	✓	100	0.00%
2	✓	100	0.00%
3	✓	100	0.00%
4	✓	100	0.00%
5	✓	100	0.00%
FORGE TEST			
1	✓	99.76	0.00%
2	✓	83.44	0.00%
3	✓	72.22	0.00%
4	✓	83.93	0.00%
5	✓	99.93	0.00%

Table 14. Person X Signature Sample Test

PERSON Y			
TRIAL	**AUTHENTICITY**	**ACCURACY(%)**	**% ERROR**
GENUINE TEST			
1	✓	99.18	0.00%
2	✓	98.95	0.00%
3	✓	99.82	0.00%
4	✓	100	0.00%
5	✓	100	0.00%
FORGE TEST			
1	✓	57.39	0.00%
2	✓	94.57	0.00%
3	✓	84.72	0.00%
4	✓	99.67	0.00%
5	✓	99.92	0.00%

Table 15. Person Y Signature Sample Test

PERSON Z			
TRIAL	**AUTHENTICITY**	**ACCURACY(%)**	**% ERROR**
GENUINE TEST			
1	✓	100	0.00%
2	✓	100	0.00%
3	✓	99.85	0.00%
4	✓	100	0.00%
5	✓	100	0.00%
FORGE TEST			
1	✓	100	0.00%
2	✓	99.98	0.00%
3	✓	100	0.00%

4	✓	100	0.00%
5	✓	100	0.00%

Table 16. Person Z Signature Sample Test

For each trial, the verification result that was displayed in the TFT LCD Touchscreen was observed if the verification was a success after the proponents tapped the compare button. Each test for every signature input was marked with a check for successful detection and marked with a cross for a failure to match the reading. As highlighted in Table 15, the trial 6 of Person Y Signature sample test displayed a 57.39% accuracy which was lower than usual. Nevertheless, the system was able to verify the 30 trials of signatures accurately. Using the formula presented in the research methodology, it was found out that the project has a 0% error when it comes to the accuracy of the handwritten signature being input.

E. Manual versus System Signature Verification

The comparison between manual and system-based verification was conducted using a test questionnaire consisting of 30 signature samples from persons in which the model was trained. The 30 samples were divided by 10 samples per person, divided equally into 5 genuine and 5 forged signature specimens. The respondents verified the specimens visually using their expert judgment and prior knowledge. The individual scores of each respondent per item in the test questionnaire were recorded and tabulated. The system verification was performed using the system prototype, wherein the signatures were verified one by one. The verification result displayed in the LCD Touchscreen were recorded and tabulated. The results of the manual and system method were tested using the Mann-Whitney U Test. The Manual versus System Signature Verification was tested using The Mann-Whitney U Test. The Mann-Whitney U Test is a statistical test that determines if two groups differ significantly on your variable of interest. Data encoding, codifying, data cleaning, and analyses were performed using Statistical Package for the Social Sciences (SPSS) version 20.0. The results from the Manual and System were then evaluated in the SPSS software. This was used in order to compare the differences between the Manual and System. The alpha level was set at 0.05 to determine statistical significance.

F. Tabulation Survey Test Questionnaire Result

It was observed by the researchers that no tool or software was used by any of the respondents. The respondents made mention of the existence of such tools or software but respondents neither had access to it or made use of it extensively. The common practice is still verifying signatures visually by comparing them to existing signature specimens.

Based on the table presented below, none of the items got the perfect score from the 73 respondents. Highlighted above the table, are the items that obtained the lowest score from the respondents in manual test.

ITEM	ANSWER	#PEOPLE CORRECT ANSWER	#PEOPLE WRONG ANSWER
1	B	66	7
2	B	63	10
3	**A**	**55**	**18**
4	B	62	11
5	A	62	11
6	A	62	11
7	**A**	**59**	**14**
8	**B**	**52**	**21**
9	**A**	**44**	**29**
10	A	61	12
11	B	62	11
12	A	63	10

13	B	68	5
14	B	67	6
15	B	65	8
16	A	62	11
17	A	65	8
18	B	65	8
19	B	63	10
20	B	66	7
21	A	67	6
22	A	67	6
23	B	67	6
24	B	66	7
25	B	65	8
26	A	66	7
27	B	64	9
28	B	64	9
29	A	65	8
30	B	66	7

Table. 17 Tabulation Survey Test Questionnaire Result

It was observed by the researchers that no tool or software was used by any of the respondents. The respondents made mention of the existence of such tools or software but respondents neither had access to it or made use of it extensively. The common practice is still verifying signatures visually by comparing them to existing signature specimens. Based on the table presented above, none of the items got the perfect score from the 73 respondents. Highlighted above the table, are the items that obtained the lowest score from the respondents in manual test.

		A		B	
Items	Answer	Authenticity	Accuracy(%)	Authenticity	Accuracy(%)
1	B	✓	100	✓	93.68
2	B	✓	100	✓	56.31
3	A	✓	100	✓	56.45
4	B	✓	100	✓	91.95
5	A	✓	100	✓	74.46
6	A	✓	100	✓	85.37
7	A	✓	100	✓	55.21
8	B	✓	100	✓	99.95
9	A	✓	100	✓	98.19
10	A	✓	100	✓	99.86
11	B	✓	100	✓	94.38
12	A	✓	100	✓	51.97
13	B	✓	89.82	✓	62.52
14	B	✓	98.95	✓	97.97
15	B	✓	94.24	✓	91.19
16	A	✓	94.17	✓	99.67
17	A	✓	99.98	✓	99.92
18	B	✓	99.66	✓	99.95
19	B	✓	99.98	✓	99.96
20	B	✓	100	✓	99.9

21	A	✓	100	✓	99.88
22	A	✓	99.9	✓	100
23	B	✓	100	✓	100
24	B	✓	99.27	✓	99.76
25	B	✓	100	✓	99.98
26	A	✓	99.33	✓	99.99
27	B	✓	100	✓	100
28	B	✓	100	✓	99.98
29	A	✓	100	✓	99.85
30	B	✓	100	✓	100

Table 18. Test Questionnaire System Result

The proposed device system was used to compare the result of the manual signature verification. Each item and its corresponding choices A and B were tested in the device. The results from the system were recorded and tabulated.

Shown in the Table 18 are the result of system verification result. The highlighted items number: 3,7,12 and 13 obtained the low confidence level accuracy from the system results. Nevertheless, the results of all items in the test questionnaire were successfully read by the device system.

The results from Table 17 and 18 were fed in the SPSS using the MannWhitney U-Test. The table below shows the result of the Mann-Whitney U Test in SPSS after specifying the tabulation of the survey test questionnaire results and Detection and Verification System of Handwritten Signatures.

Method	**Manual**	**System**
N	30	30
Mean	86.6	90.3
Maximum	93.2	100.0
Minimum	60.3	52.0
Standard Deviation	7.0	16.4
Mean Rank	22.4	38.6
Mann-Whitney U Test Statistics	207.000	
P-Value	0.000	
Decision	**Reject$_{H0}$**	

Table. 19 Test of Significant Difference between the Accuracy of Manual and System

The Mann-Whitney U test yielded a **p-value < 0.05**, indicating a statistically significant difference in accuracy between the manual and system verification methods. Thus, the system demonstrated superior reliability and performance.

The Mann-Whitney test compares the mean rank of each group after converting scores into ranks. The table above indicates between the Manual and System can be considered as having the better performance in signature verification; namely, the group with the highest Mean and Mean Rank. As observed in Table 19, there was a sizeable difference between the mean and mean ranks of Manual and System. In this case, the System had the highest accuracy in verifying signatures. The null hypothesis must be rejected since the difference between the mean ranks is large enough to be significant. The table above revealed that the system method is reliable and accurate than the manual method in verifying the signatures of Person X, Y and Z.

Test Statistics	
	Accuracy
Mann-Whitney U	207.000
Wilcoxon W	672.000
Z	-3.596
Asymp. Sig. (2-tailed)	.000
Grouping Variable: Independent	

Table 20. Test Statistics

The SPSS produces a test statistic that summarized the result of the MannWhitney U test. The key values are Mann-Whitney U, Z, and the 2-tailed significance score. As stated in the Table 24, the SPSS reports a Z score of -3.596 and a 2-tailed p-value of .000. These results can be considered a significant result since the standard alpha level is 0.05.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Accuracy is the same across categories of Independent.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Fig. 20 Result for the Test of Significant Difference between the Accuracy of Manual and System

Thus, the result of Mann-Whitney U test shows that there is sufficient evidence to conclude a significant difference between the accuracy level of manual and system. The Mann-Whitney U test results supports that the Manual and Detection and Verification System of Handwritten Signatures had statistically significant difference.

Based on the results of Table 19, 20 and Figure 20, the system method in detecting and verifying hand written signatures performs better than the manual method.

V. CONCLUSION

This study provided a statistical comparison between a machine learning-based handwritten signature verification system, and a traditional manual verification method. The system was acceptable and capable of verifying genuine and forged signature inputs. It utilizes Raspberry Pi which it integrated the LeNet algorithm model that processes the verification of the captured signature input. The System Acceptability Evaluation Procedure survey items that achieved highest score of 4.8 were items number 3, 7, 10 wherein the system was user-friendly, easy to use and a "Very Good" rating on the overall rating for the detection and verification system. The test results were successful, and the technical evaluations showed a total mean score of 4.6 which was interpreted as "Very Good" presented in the previous chapter.

1. The developed system effectively verified handwritten signatures using Raspberry Pi with a TFT LCD touchscreen and camera module.
2. The integrated LeNet ANN achieved 99.36% accuracy with a 1.4% loss, outperforming other tested algorithms.
3. Survey results indicated high acceptability and reliability (grand mean 4.6, Cronbach's alpha 0.728).
4. The Mann-Whitney U test provided a statistical comparison over manual verification ($p < 0.05$).

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APPENDIX A

Survey Instrument Validation Rating Scale

Instruction: Please indicate your degree of agreement or disagreement on the statements provided below by encircling the number which corresponds to your best to your judgment.

1 – Strongly Disagree 2 – Disagree 3 – Undecided 4 – Agree 5 – Strongly Agree

Criteria					
The items in the instrument are relevant to answer the objectives of the study.	1	2	3	4	5
The items in the instrument can obtain depth to constructs being measured.	1	2	3	4	5
The instrument has an appropriate sample of items for the construct being measured.	1	2	3	4	5
The items and their alternatives are neither too narrow nor limited in its content.	1	2	3	4	5
The items in the instrument are stated clearly.	1	2	3	4	5
The items on the instrument can elicit responses which are stable, definite, consistent and not conflicting.	1	2	3	4	5
The terms adapted in the scale in the scale are culturally appropriate.	1	2	3	4	5
The layout or format of the instrument is technically sound.	1	2	3	4	5
The responses on the scale show a reasonable range of variation.	1	2	3	4	5
The instrument is not too short or long enough that the participants will be able to answer it within a given time.	1	2	3	4	5
The instrument is interesting such that participants will be induced to respond to it and accomplish it fully	1	2	3	4	5

The instrument as a whole could answer the basic purpose for which it is designed.	1	2	3	4	5
The instrument is culturally acceptable when administered in the local setting	1	2	3	4	5

Survey Questionnaire

Title/Name of System/Software being evaluated: "Detection and Verification System of Handwriting and Signatures Using Raspberry Pi"
Name of Evaluator (Optional):
Designation:
Office/Company:
Date:
Instruction: Kindly evaluate the degree of compliance of the system using the survey questionnaire created for this study by checking the column corresponding the degree to which you deemed the system being evaluated complied or achieved using the scale below.

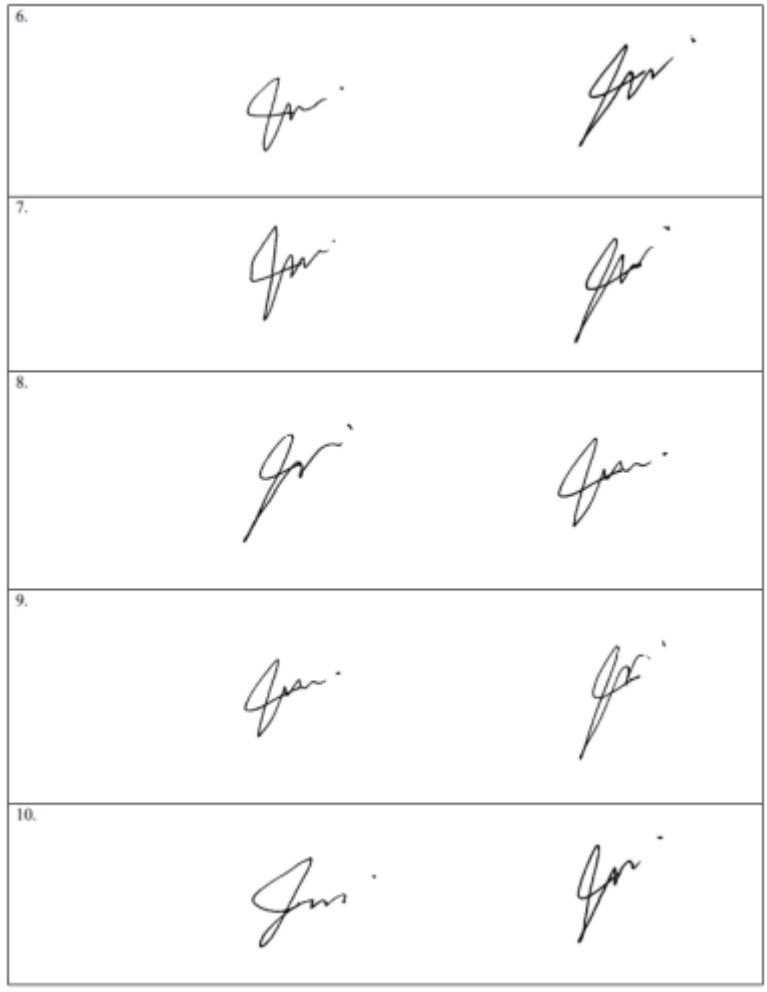
Legend:
5 – Very Good;
4 – Good;
3 – Average;
2 – Poor;
1 – Very Poor
At a scale of 1 to 5, with the 5 the highest, please rate out research according to the following statements.

STATEMENT	5	4	3	2	1
1. Detection and verification of signatures are faster than the conventional or manual method.					
2. The device is easy to use and is convenient.					
3. The User Interface (UI) of the device is user-friendly.					
4. The prototype device is presentable and aesthetically acceptable.					
5. Processing inputs to the device is easy and convenient.					
6. The assistance of a technical person is required to use this system.					
7. The instruction provided with the system is clear and easy to understand.					
8. The information outputs of the system is meaningful and appropriate					
9. Signature verification and detection results of the system is accurate.					
10. The overall rating for the detection and verification system.					

TEST QUESTIONNAIRE

PERSON X		
GENUINE #1	GENUINE #2	GENUINE #3
		

ANSWER	A	B
1.		
2.		
3.		
4.		
5.		



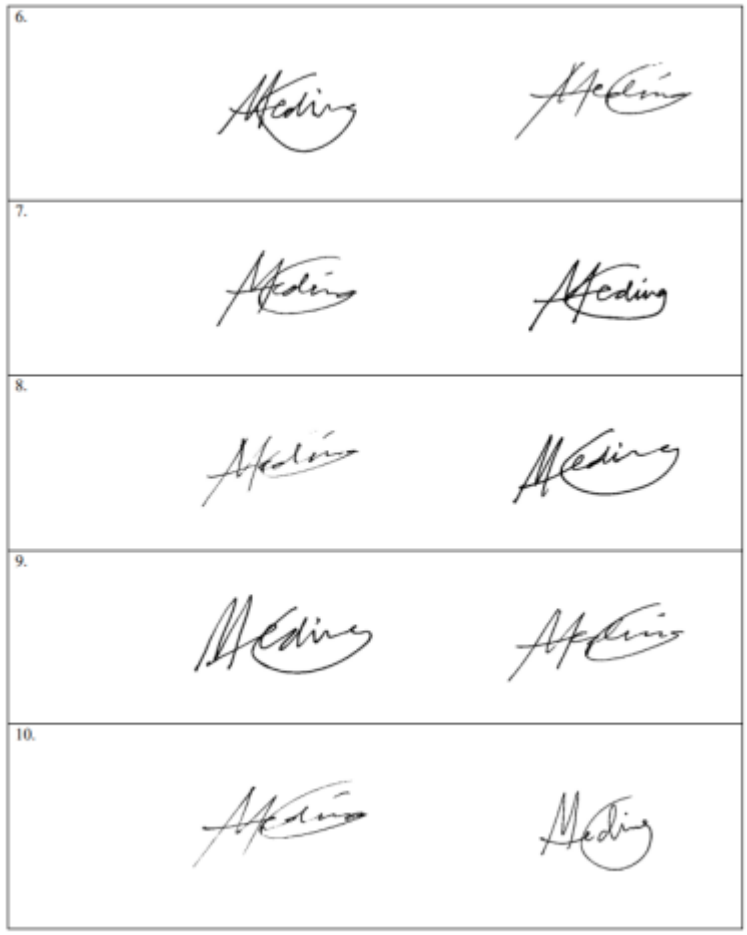
PERSON Y		
GENUINE #1	GENUINE #2	GENUINE #3
		

ANSWER	A	B
1.		
2.		
3.		
4.		
5.		

6.		
7.		
8.		
9.		
10.		

PERSON Z		
GENUINE #1	GENUINE #2	GENUINE #3
		

ANSWER	A	B
1.		
2.		
3.		
4.		
5.		



APPENDIX B

Tabulation of Results

Survey Instrument Acceptability Evaluation

Participants	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	SUM
No.1	5	4	4	4	5	5	5	5	5	5	5	5	4	61
No.2	5	5	5	5	5	5	5	5	5	5	5	5	5	65
No.3	5	5	5	4	5	5	4	5	5	5	5	5	5	63
No.4	5	5	5	5	5	5	5	5	5	5	5	5	5	65
No.5	5	5	5	5	5	4	5	4	5	5	5	5	5	63
Sum	25	24	24	23	25	24	24	24	25	25	25	25	24	317
Mean	5	4.8	4.8	4.6	5	4.8	4.8	4.8	5	5	5	5	4.8	63.4

Survey Instrument Reliability Evaluation

F2F Survey 11
Google Forms 19
30

PARTICIPANTS	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	total
No.1	5	5	5	5	5	5	5	5	5	5	50
No.2	5	5	5	5	5	4	4	5	4	4	46
No.3	5	4	4	5	5	5	5	5	5	5	48
No.4	5	5	4	5	4	5	4	4	5	5	46
No.5	5	5	5	5	5	5	5	5	5	5	50
No.6	5	5	3	5	4	4	5	4	4	4	43
No.7	5	5	5	5	5	5	5	5	5	5	50
No.8	5	5	5	5	5	5	5	5	5	5	50
No.9	5	5	5	5	5	5	5	5	5	5	50
No.10	5	5	4	4	3	5	4	5	4	4	43
No.11	5	5	4	5	5	5	5	5	5	5	49
No.12	5	5	5	5	5	5	5	5	5	5	50
No.13	5	5	5	5	5	5	5	5	5	5	50
No.14	5	5	5	5	5	3	5	5	5	5	48
No.15	5	4	5	5	5	5	5	5	5	5	49
No.16	5	5	5	5	5	5	5	5	5	5	50
No.17	5	5	4	5	5	5	5	5	4	5	48
No.18	5	4	5	5	5	5	5	5	4	5	48
No.19	5	5	5	4	5	4	5	4	5	4	46
No.20	5	5	5	4	5	5	5	5	5	5	49
No.21	5	5	5	5	5	4	5	5	5	5	49
No.22	5	5	5	5	5	5	5	5	5	5	50
No.23	5	5	5	5	5	5	5	5	5	5	50
No.24	5	5	5	5	5	5	5	5	5	5	50
No.25	4	4	5	4	5	5	4	5	5	5	46
No.26	5	5	5	5	5	5	5	5	5	5	50
No.27	5	4	5	5	4	4	5	4	4	5	45
No.28	5	5	5	5	5	5	5	5	5	5	50
No.29	5	5	4	5	5	5	5	5	5	5	49
No.30	5	5	5	5	5	5	5	5	5	5	50
variances	0.03222	0.13889	0.26222	0.11556	0.20556	0.24556	0.11556	0.11556	0.16	0.11556	14 52

Scale Statistics			
Mean	Variance	Std. Deviation	Number of Items
48.40	4.524	2.127	10

Reliability Statistics		
Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	Number of Items
.728	.733	10

System Acceptability Evaluation

F2F Survey 40
Google Forms 33
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PARTICIPANTS	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUM
No.1	4	5	5	4	5	5	4	4	5	5	46
No.2	3	4	4	4	5	4	5	5	4	4	42
No.3	5	5	5	5	5	5	5	5	5	5	50
No.4	4	3	4	4	5	5	5	5	5	5	45
No.5	4	5	5	4	4	4	4	5	5	5	45
No.6	5	5	5	5	5	5	4	4	3	4	45
No.7	5	5	5	5	5	5	5	5	5	5	50
No.8	5	5	5	5	5	5	5	5	5	5	50
No.9	5	5	5	5	5	5	5	5	5	5	50
No.10	4	5	4	4	5	5	5	5	5	5	47
No.11	5	5	5	5	5	5	5	5	5	5	50
No.12	5	5	5	5	5	5	5	5	5	5	50
No.13	5	5	5	5	5	5	5	5	5	5	50
No.14	4	4	4	4	4	4	4	4	4	4	40
No.15	3	4	4	4	3	4	4	4	4	4	38
No.16	5	5	5	5	5	5	5	5	5	5	50
No.17	5	5	5	5	5	5	5	5	5	5	50
No.18	5	5	5	5	4	4	5	4	5	5	47
No.19	5	5	5	5	5	5	5	5	5	5	50
No.20	5	5	5	5	5	5	5	5	5	5	50
No.21	5	3	3	5	4	4	4	5	5	5	43
No.22	5	5	5	4	5	5	5	5	5	5	49
No.23	5	5	5	4	5	2	5	4	5	5	45
No.24	5	4	4	5	4	4	5	4	4	4	43
No.25	5	5	5	4	5	5	5	5	5	5	49
No.26	5	5	5	5	5	5	5	5	5	5	50
No.27	5	5	5	4	5	4	5	5	5	5	48
No.28	3	3	4	3	5	4	4	5	4	4	39
No.29	4	5	5	4	5	3	5	4	4	5	44
No.30	5	4	3	4	4	2	4	4	4	4	38
No.31	4	4	5	3	4	3	5	4	4	4	40
No.32	5	5	5	5	5	4	5	5	5	5	49

No.33	5	5	4	4	5	5	5	5	5	5	48
No.34	4	5	5	4	4	4	5	5	4	4	44
No.35	4	5	4	4	4	3	5	3	3	4	39
No.36	5	5	4	4	5	4	5	5	3	5	45
No.37	5	5	5	5	5	5	5	5	5	5	50
No.38	5	5	5	5	5	5	5	5	5	5	50
No.39	4	4	5	5	5	4	5	5	4	4	45
No.40	5	5	5	5	5	5	5	5	5	5	50
No.41	5	5	5	5	4	5	4	4	5	5	47
No.42	5	4	5	5	4	3	5	4	5	4	44
No.43	3	4	5	5	5	4	5	4	5	4	44
No.44	4	4	4	3	4	5	4	4	3	4	39
No.45	4	5	4	5	4	5	5	5	5	5	47
No.46	5	5	5	5	5	5	5	5	5	5	50
No.47	4	5	4	3	4	4	4	4	3	4	39
No.48	5	5	5	4	4	5	5	4	5	5	47
No.49	5	5	5	5	5	5	5	5	5	5	50
No.50	5	5	5	5	5	5	5	5	5	5	50
No.51	5	5	5	5	5	5	5	5	5	5	50
No.52	5	5	5	5	5	5	5	5	5	5	50
No.53	5	4	5	5	3	5	4	5	5	5	46
No.54	5	5	5	5	4	4	4	5	5	5	47
No.55	4	4	4	4	5	4	4	5	5	4	43
No.56	5	4	5	5	5	5	5	5	5	5	49
No.57	5	5	5	3	5	5	5	4	4	5	46
No.58	5	4	5	5	5	5	5	5	5	5	49
No.59	4	4	5	4	5	5	5	5	4	5	46
No.60	5	5	5	5	5	5	5	5	5	5	50
No.61	5	5	5	5	5	4	5	5	5	5	49
No.62	5	5	5	5	5	5	5	5	5	5	50
No.63	5	5	5	5	4	4	4	4	4	4	44
No.64	5	5	5	4	4	5	5	4	5	5	47
No.65	5	5	5	5	5	5	5	5	5	5	50
No.66	5	5	5	5	5	5	5	5	5	5	50
No.67	4	5	5	5	5	5	5	4	4	5	47
No.68	5	5	5	5	5	5	5	5	5	5	50
No.69	5	5	5	5	5	5	4	4	4	5	47
No.70	5	5	5	5	5	5	5	5	5	5	50
No.71	5	5	5	5	5	5	5	5	5	5	50
No.72	5	5	5	5	5	5	5	5	5	5	50
No.73	5	5	5	5	5	4	4	4	4	5	46
SUM	341	344	347	334	343	331	348	341	339	348	3416
MEAN	4.7	4.7	4.8	4.6	4.7	4.5	4.8	4.7	4.6	4.8	**46.7945**

System Performance Evaluation

System Accuracy Evaluation

Test Samples	Authenticity	Percentage
1	✓	100%
2	✓	100%
3	✓	100%
4	✓	100%
5	✓	100%
6	✓	99.76%
7	✓	83.44%
8	✓	72.22%
9	✓	83.93%
10	✓	99.93%
11	✓	99.18%
12	✓	98.95%
13	✓	99.82%
14	✓	100%
15	✓	100%
16	✓	57.39%
17	✓	94.57%
18	✓	84.72%
19	✓	99.67%
20	✓	99.92%
21	✓	100%
22	✓	100%
23	✓	99.85%
24	✓	100%
25	✓	100%
26	✓	100%
27	✓	99.98%
28	✓	100%
29	✓	100%
30	✓	100%

Manual Versus Handwritten Signature Verification System

PERSON X				
NUM.	**A**		**B**	
	Authenticity	**Accuracy (%)**	**Authenticity**	**Accuracy (%)**
1	✓	100	✓	93.68
2	✓	100	✓	56.31
3	✓	100	✓	56.45
4	✓	100	✓	91.95
5	✓	100	✓	74.46
6	✓	100	✓	85.37
7	✓	100	✓	55.21
8	✓	100	✓	99.95
9	✓	100	✓	98.19
10	✓	100	✓	99.86
PERSON Y				
	Authenticity	**Accuracy (%)**	**Authenticity**	**Accuracy (%)**
11	✓	100	✓	94.38
12	✓	100	✓	51.97
13	✓	89.82	✓	62.52
14	✓	98.95	✓	97.97
15	✓	94.24	✓	91.19
16	✓	94.17	✓	99.67
17	✓	99.98	✓	99.92
18	✓	99.66	✓	99.95
19	✓	99.98	✓	99.96
20	✓	100	✓	99.9
PERSON X				
	Authenticity	**Accuracy (%)**	**Authenticity**	**Accuracy (%)**
21	✓	100	✓	99.88
22	✓	99.9	✓	100
23	✓	100	✓	100
24	✓	99.27	✓	99.76
25	✓	100	✓	99.98
26	✓	99.33	✓	99.99
27	✓	100	✓	100
28	✓	100	✓	99.98
29	✓	100	✓	99.85
30	✓	100	✓	100

MANUAL VERSUS SYSTEM SIGNATURE VERIFICATION
SPSS MANN-WHITNEY U TEST RESULT

Test of Normality

When respondents in n>50, test of Normality using Kolmogorov-Smirnov is appropriate. P-values of the measure of accuracy is p<0.05, data significantly deviate from a normal distribution. This leads to the use of Non-parametric Tests:

Mann-Whitney U Test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Accuracy	.208	60	.000	.800	60	.000
a. Lilliefors Significance Correction						

Statistical Test Raw

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Accuracy	60	88.4260	12.60999	51.97	100.00
Independent	60	1.50	.504	1	2

Ranks

Independent		N	Mean Rank	Sum of Ranks
Accuracy	Manual	30	22.40	672.00
	System	30	38.60	1158.00
	Total	60		

	Accuracy
Mann-Whitney U	207.000
Wilcoxon W	672.000
Z	-3.596
Asymp. Sig. (2-tailed)	.000

Test Statistics[a]

a. Grouping Variable: Independent

Table 1

		Accuracy			
		Mean	Maximum	Minimum	Standard Deviation
Independent	Manual	86.58	93.15	60.27	6.95
	System	90.28	100.00	51.97	16.37

MANUAL VERSUS SYSTEM SIGNATURE VERIFICATION MANUAL

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PARTICIPANTS	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30
No.1	B	B	A	B	A	A	A	A	B	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.2	B	B	B	B	A	A	A	A	B	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	A	A	B	B	A	B
No.3	B	B	B	B	A	A	A	B	B	A	B	A	B	B	B	A	A	B	A	B	A	A	B	B	B	A	A	A	A	B
No.4	B	B	B	B	A	A	A	A	A	A	B	A	B	B	B	A	A	B	B	A	A	A	B	A	A	A	B	A	A	A
No.5	B	B	A	B	A	A	A	B	B	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	B	A
No.6	B	B	A	B	A	A	A	B	A	A	A	A	B	B	B	A	A	B	A	B	A	A	B	B	B	A	B	B	A	B
No.7	B	B	A	B	A	A	A	A	B	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.8	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.9	B	B	A	B	A	A	A	B	B	A	B	B	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.10	A	A	B	A	B	B	B	A	B	A	B	B	B	B	B	B	B	B	B	B	A	A	A	B	B	A	A	B	A	B
No.11	B	B	A	B	A	A	B	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	A	A	B
No.12	B	B	A	B	A	A	A	A	B	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.13	B	B	A	B	A	A	A	A	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.14	B	B	A	B	A	A	A	A	B	A	A	A	A	B	A	B	A	B	A	B	A	A	B	B	A	A	B	B	A	B
No.15	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.16	A	A	B	A	B	B	B	A	B	B	A	A	B	A	A	A	A	A	B	A	A	A	B	B	B	A	B	B	A	B
No.17	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	B	B	B	B	A	B	B	B	B
No.18	B	B	A	B	A	A	A	A	B	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.19	B	B	B	B	A	A	A	A	B	B	B	A	B	B	B	B	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.20	B	A	B	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B

No.21	B	B	A	B	B	A	B	B	B	B	B	A	B	B	B	A	A	B	B	B	A	A	B	B	A	A	B	B	A	B
No.22	B	B	A	B	A	A	A	B	B	A	A	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.23	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.24	B	B	B	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.25	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.26	A	A	B	A	B	B	B	B	B	B	A	B	A	A	A	B	B	A	A	A	B	B	A	A	B	B	A	A	B	A
No.27	B	B	A	A	B	B	B	B	B	B	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.28	A	A	B	A	B	B	B	B	B	A	B	B	A	A	A	B	B	A	A	A	B	B	A	A	A	B	A	A	B	A
No.29	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.30	B	B	A	B	A	A	A	B	B	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.31	B	B	A	A	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.32	B	B	B	B	A	A	A	B	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B	B
No.33	B	B	A	B	A	B	A	A	B	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.34	B	B	A	B	A	B	A	B	B	A	B	A	B	B	B	B	B	B	B	B	A	A	B	B	B	B	A	A	A	B
No.35	B	A	A	B	A	A	A	A	B	A	B	A	B	B	B	A	A	B	B	B	A	A	A	B	B	A	B	B	A	B
No.36	B	B	A	B	A	A	A	A	B	B	B	A	B	B	B	A	A	A	A	B	A	A	B	B	B	A	B	B	A	B
No.37	A	A	B	A	B	B	B	A	A	B	A	B	A	A	A	B	B	A	A	A	B	B	A	A	A	B	A	A	B	A
No.38	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.39	B	B	A	B	A	A	A	A	B	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.40	B	B	B	B	A	A	A	A	A	A	B	A	B	B	A	A	A	B	B	B	A	A	B	A	B	A	B	A	B	B
No.41	B	B	A	B	A	A	B	A	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	A	B	B	A	B	A	B
No.42	A	A	B	A	B	B	B	B	A	B	A	B	B	A	A	B	B	A	A	A	B	B	A	A	A	B	A	A	B	A
No.43	B	B	A	B	A	A	A	B	B	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.44	B	B	B	A	A	A	A	B	A	A	A	A	B	B	B	A	A	B	B	B	B	A	B	B	B	A	B	B	A	B
No.45	B	B	A	B	A	A	A	B	A	B	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.46	B	A	A	B	A	A	B	B	A	A	B	B	B	B	B	B	A	B	B	B	A	A	B	B	B	A	A	B	A	B
No.47	B	B	A	A	A	A	B	B	B	B	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	A	B	A	B
No.48	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.49	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.50	A	A	B	A	B	B	B	A	B	B	A	B	A	A	A	B	B	A	A	A	A	A	B	B	A	B	B	B	A	B

No.51	B	B	B	B	B	A	A	A	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.52	B	B	A	B	A	A	A	B	A	A	B	B	B	B	B	A	A	A	B	B	A	A	B	B	B	A	B	B	A	B
No.53	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
No.54	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.55	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.56	B	B	A	B	A	A	A	B	B	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.57	B	B	A	B	A	A	A	B	A	A	A	A	B	B	B	A	A	B	A	B	A	A	B	B	B	A	B	B	A	B
No.58	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.59	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.60	B	B	A	B	A	A	A	B	A	A	A	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.61	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.62	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.63	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.64	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.65	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.66	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.67	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.68	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.69	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.70	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	A
No.71	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.72	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B
No.73	B	B	A	B	A	A	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	B	B	A	B	B	A	B

