Multiple-Barcode Verification using Image Processing Technique for Mobile Phone Packaging

Phakamat Mingkhwan, Sarinya Sala-ngam, Alongkorn Lamom, Krittanon Prathepha

and Chonlatee Photong[*]

Faculty of Engineering, Mahasarakham University, Kham Riang, Kantharawichai, Maha Sarakham, 44150, Thailand

phakamat.biw@gmail.com and chonlatee.p@msu.ac.th[*]

Abstract. *Barcodes play an important role for industrial manufacturing and packaging processes or inspections due to their fast, cheap and relatively high accuracy compared to human's recognition. However, most barcode readers can read only one barcode at a time while some inspection processes would require multiple barcode reading for saving working time of operators. This research proposes a multiple-barcode verification using the commonly used NI Vision image processing program for mobile phone packaging process. The verification system consists of cameras with a lighter and a NI Vision 2018 image processing program. The program read 8-20 barcodes at a time from a photograph captured by the fixed-position camera. The experimental test results showed that the proposed system spent only 5-7 seconds for 10-barcodes verification, which was faster than the human's operation with one-by-one scanning (19-27 seconds) and thus save working time by 3-4 times. In addition, the proposed system also provided high accuracy of 98.64%, which was better than human's operation (94.04%) by 4.60%.*

1. Introduction

Barcodes are one of the most commonly used tools for industrial manufacturing and production processes in Thailand due to its simple in use, rather low operation cost and save working time when compared to human's [1]. The researchers have experienced working in a mobile phone assembling company in Thailand. The company has used barcodes for several processes and one of those is in the mobile phone packaging and inspecting processes. The barcodes are used to identify each individual mobile phone box and its master box (containing 10-20 mobile phone boxes), which are needed to be read and recorded for daily inspection and product history record. However, every master box packaging spends the time of 19.03-71.03 seconds per box to complete the barcode reading and

recording with the average accuracy of 94.04%, varying dependent on the worker's experience and practicum. This large variation in working time and less accuracy would lead to the problem of difficulty in the working time and budget planning and control for the company.

To overcome this problem, some possible solutions have been studied. There are few technologies available for barcode reading and recording. The first group technology is to use the mobile phones with deformable templates as shown in Fig.1 [2], i.e., ZXing3 (C++ version) library [3], Deep Learning [4] and the Bars Detection Method [5] The second group technology is to use the edge detection and morphological operation by MATLAB platform [6], Visual C ++ [7], CCD camera to collect pictures, adopts the HALCON to build the processing algorithm, and uses Visual Studio platform to build the software as shown in Fig. 2 [8], and Cognex VisionPro [9]. The third technology when review similar applications for most industrial manufacturing companies in Thailand, it seems that several companies trend to use image processing technology more for their production, packaging or inspection processes. This is because of the fact that this technology provides fast operation, rather inexpensive and high accuracy, which is commonly known in most factories as "Machine vision" [1]; e.g. using as automatic visual inspection in the hard disk drive processes [10], inspecting failures for cigarette production lines [11], checking completion of PCB boards [12], 2-diamention real-time barcode reader [9], classifying agricultural fruits and vegetables such as olive oil fruits [13] or animal incubation processes such as chicken [14]. In summary, by using image processing technique would be more preferable for the mobile phone packaging process.

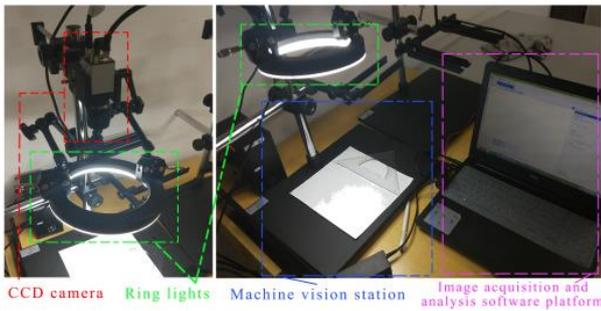**Fig. 1** Barcode reading device of Orazio Gallo et al. [2]

Fig. 2 Barcode reading device of Hui Zhang et al. [8]

Fig. 3 shows the common components used for the mobile phone packaging processes with human's operation while Fig. 4 shows the operation procedure for the barcode verification. There are 7 main devices as listed below:

1) Computer (for displaying Pass/Fail)
2) Label printer (for labeling barcodes)
3) Manual scanner (for barcode verification)
4) Master box (containing 8-20 mobile phone boxes)
5) Mobile phone box (for containing mobile phone)
6) Weighing machine (for weight inspection)
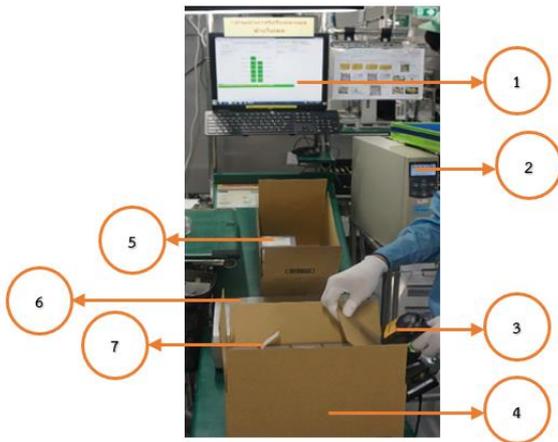7) Lifting tape (for facilitating the final checking)

Fig. 3 components used for the mobile phone packaging process.
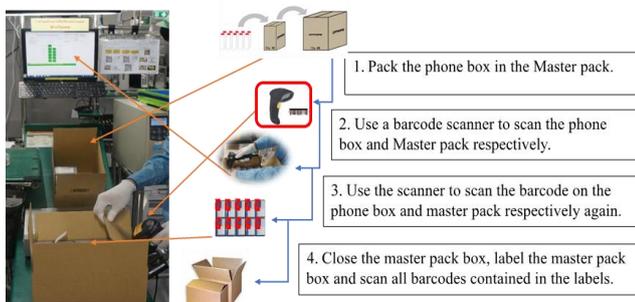

Fig. 4 operation procedure for mobile phone packaging

2. Materials and Methods

This research proposed the study of multiple-barcode verification for the mobile phone packaging boxes by using the image processing technique. This was done by applying image processing based on the Machine Vision operation platform with modified hardware structure. The hardware part consists of image acquisition equipment, two camera sensors (CCD, CMOS) and a lighting lamp [15]-[16]. The software part consists of NI Vision image processing (this would be possibly replaced also by the other such as MATLAB, Lab VIEW, OpenCV [17-18] and other series of NI Vision builder automated inspection (VBAI) [19-20], etc.) The proposed system operated real-time and conducted Pass/Fail results [21]. Details of the structure and operation of the proposed systems are described as follows.

2.1 The Proposed Structure and Operation

Fig. 5 shows the structure of the proposed multiple-barcode verification for mobile packaging process using NI Vision image processing. The system consists of two main parts: the hardware part (no.1-5) and the software part (no.6), which are listed below while Fig. 11 shows the example of the display screen for the final inspection judgment (Pass/Fail) called NI Vision builder automated inspection (VBAI):
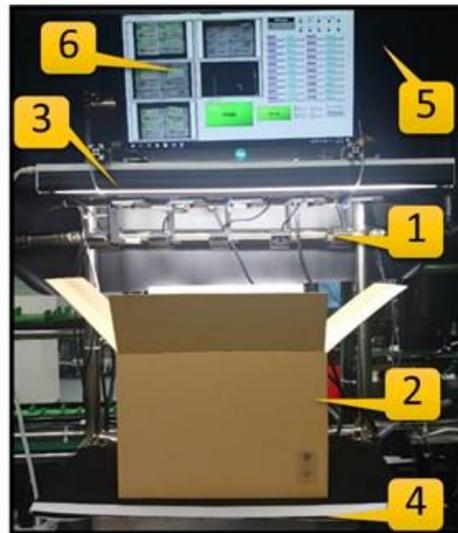

Fig. 5 components and structure of the proposed system

1) Logitech C922 webcams (for image production) was selected to produce barcode images for this research due to its relatively low price and easy to be used. Resolution of 1,920 x 1,080 pixels was set for the webcams, which was sufficient for the barcode reading.

Fig. 6 Logitech C922 Webcam [22]

2) Master box (for containing mobile phone boxes)
3) LED light bulbs
4) Box base (for fitting the position the master box)
5) Light cover (controlling light intensity)
6) NI Vision program (barcode reading and recording)

The mobile boxes were put inside the master box where each of them was labeled with a barcode sticker that was coated with moisture protecting and heat resisting substance, as well as reducing the possible scratches, as shown in Fig 7.

Fig. 7 Example photograph of the barcode stickers on the mobile box containing inside the master box

In addition, there were 3 types of the barcode stickers used in this research as follows:

1) Code 128 barcode has the physical feature as shown by the example in Fig.8. This barcode is used to replace the 39 barcode in order to increase memory capability. Furthermore, the 128 barcode has smaller in size compared to the 39 barcode.

Fig. 8 Code 128 barcode [23]

2) EAN-13 barcode is one of the barcode usually be used when more numbers are required for the products. Fig. 9 shows an example of this barcode type.

Fig. 9 EAN-13 barcode [23]

3) Data matrix or 2-diamension barcode is famous for products that have limited in area and tiny. Fig. 10 shows an example of this barcode type [23].
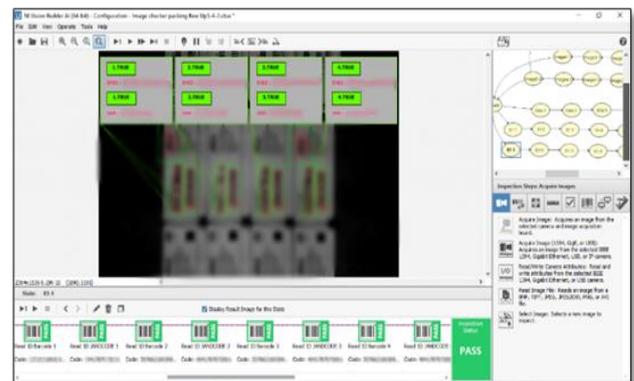

Fig. 10 Data Matrix barcode [23]

Fig. 11: Example of a display screen of the proposed system

The designed software was conducted based on the following principles:

1) Grayscale conversion is a function that converts the color image of the image from the RGB color system, in which each pixel of the color image represents RGB value using the grayscale conversion function. In image processing systems, values are specified in the range [0,1] or 0-255.
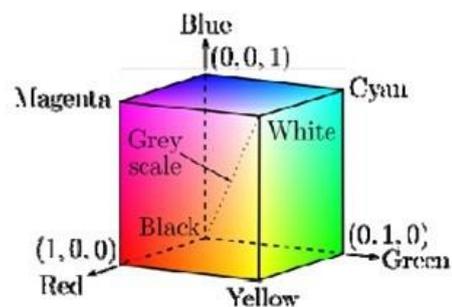

Fig. 12 RGB color model

The process of converting a color image to a grayscale image can be considered the first step from the RGB color space analysis using Eq. (1).

$$I_1(x, y) = \begin{pmatrix} I_R(x, y) \\ I_G(x, y) \\ I_B(x, y) \end{pmatrix} \qquad (1)$$

From (1) $I_1(x, y)$ is a vector image processing functions to receive particular value of each pixel at the position (x, y) in the I_1 color image, three vectors can be applied to the m matrix [24] from Eq. (2).

$$M = \left(I_1(X_R, Y_R), I_1(X_G, Y_G), I_1(X_B, Y_B)\right) \quad (2)$$

The Grayscale image gradation for converting the color (RGB) image to grayscale image, which is the continuation of white and black. This process can be converted using Eq. (3).

$$G' = 0.3R + 0.59G + 0.11B \qquad (3)$$

; where G' is the gray scale of the desired pixel, R, G and B are red, green and blue levels respectively [14, 25].

2) Edge detection of the image is the process to find the line around the object in the picture the edges of the image caused by the difference in light intensity from one point to another. If there is a big difference the edges of the image will become clearer. There are several ways to find the edges of the image. In this paper, the NI Vision edge detection was used. Edge detection is used by calculating the edge intensity in each pixel based on a 1-dimensional profile determined by the target value; where the user must define to indicate what the minimum edge intensity value is for sub-programs in NI Vision called the Contrast parameter. The program analyzed and determined the edge along the specified line by detecting a simple edge. The program used the intensity of each pixel according to the point that the profile analyzed. The program started by collecting only the data, from the first to the last pixel on that profile in the given direction. The program then found the edge position and if the rising edge had higher pixel intensity than the threshold value plus the user-defined hysteresis value, as an offset setting. As the intensity values of the rising and falling edges usually have different changing in characteristics; hence, the hysteresis setting is the same as compensating for the error that may occur. For detecting the bottom edge was done in the same way. When the pixel was below the edge, this pixel was used as a starting point to determine where the bottom edge should be. The process of finding an edge was repeated until the end of the audit profile finished, as shown in Fig. 13. The advantage of this simple edge detection is less calculation, relatively low noise and variety of different subjects and backgrounds.
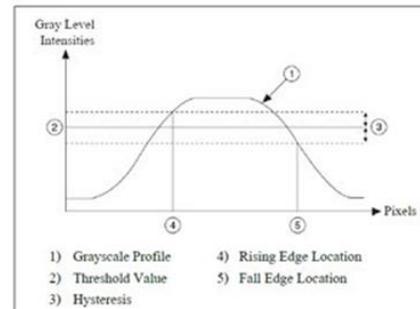

Fig. 13 Shows simple edge detection

To read the barcode the bars and spaces are counted by detecting their edges.

2.1) Edge Determination (Pass/Fail), which was illustrated in Fig. 14 and Fig. 15 for 'Pass' and 'Fail', respectively [26]. The Eq. (4) was used for the determination:

$$GT = R_{min} + SC / 2 \qquad (4)$$

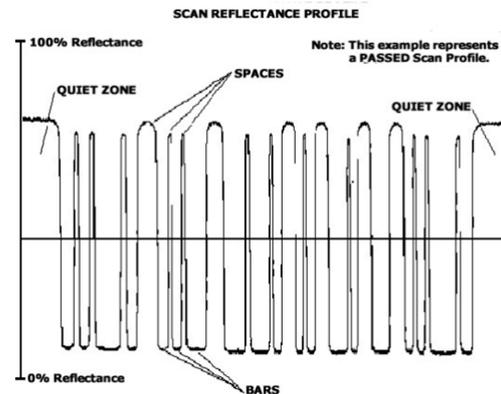; where GT refers to Global Threshold, R_{min} to minimum reflection and SC to the Symbol Contrast.

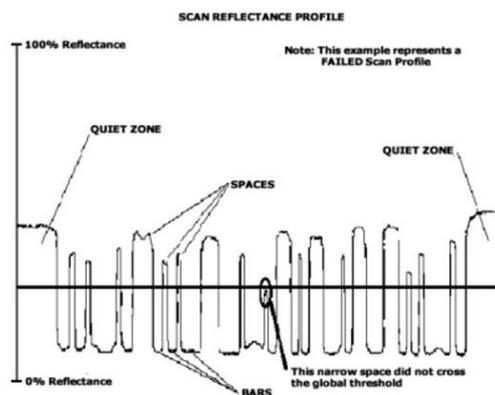**Fig. 14** Edge Determination with 'PASS' [26]

Fig. 15 Edge Determination with 'Fail' [26]

Edge determination can be achieved by counting the number of the Global Threshold as demonstrated in Fig. 16 and Fig. 17 for 'Pass' edge and 'Fail' edge determination, respectively.
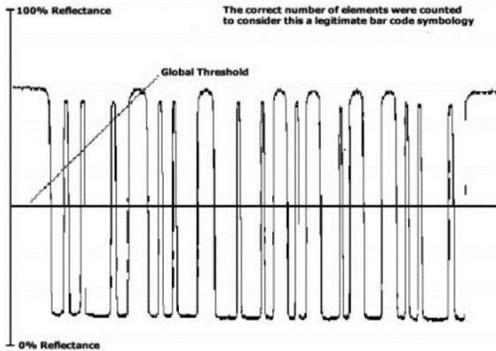

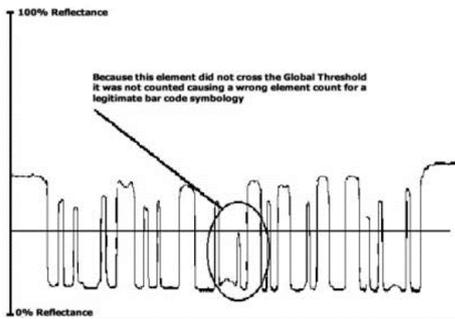**Fig. 16** Pass Edge determination [26]

Fig. 17 Fail Edge determination [26]

After passing the edge determination, there were 8 parameters to be analyzed by categorizing the quality of detection into 5 grades: 4 (A), 3 (B), 2 (C), 1 (D) or 0 (F); where 4 (A) was the best and 0 (F) was the worst (fail), more detail in [26].

2.2) Minimum Reflectance (Pass/Fail), Eq.(5)-(6) were used for the calculation:

$$R_{min} \leq 0.5R_{max} = Pass \qquad (5)$$

$$R_{min} > 0.5R_{max} = Fail \qquad (6)$$

; where R_{min} refers to the minimum reflectance and R_{max} to the maximum reflectance. The reading will be 'Pass' when R_{min} of at least 1 bar must equal or less than half of R_{max}, i.e., if R_{max} =80%, at least 1 bar must have R_{min} with equal or less than 40% as shown in Fig. 18 and Fig. 19, respectively.
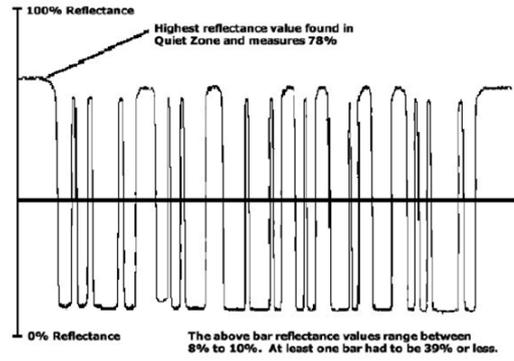
Fig. 18 Minimum reflectance (Pass) [26]
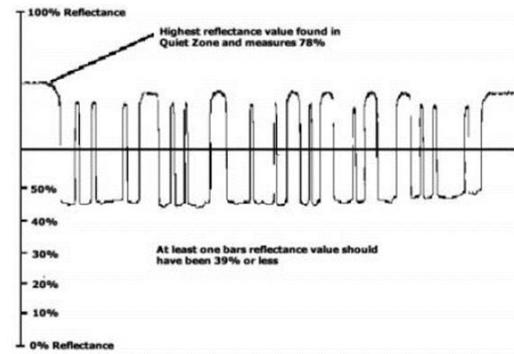
Fig. 19 Minimum reflectance (Fail) [26]

2.3) Minimum edge contrast or EC_{min} (Pass/Fail), can be calculated by using Eq. (7).

$$EC_{min} = Rs_{min} - Rb_{max} \left(Worst\ pair \right) \qquad (7)$$

; where Rs is the space reflectance and Rb is the bar reflectance:

If $EC_{min} \geq 15\%$, the reading will be 'Pass', which equal to A or 4, as shown in Fig. 20.

If $EC_{min} < 15\%$, the reading will be 'Fail', which equal to F or 0, as shown in Fig. 21.
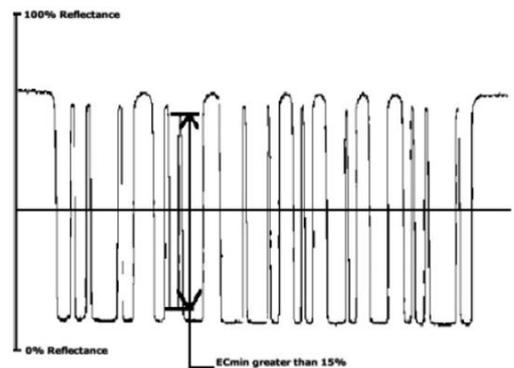
Fig. 20 Minimum edge contrast (Pass) [26]
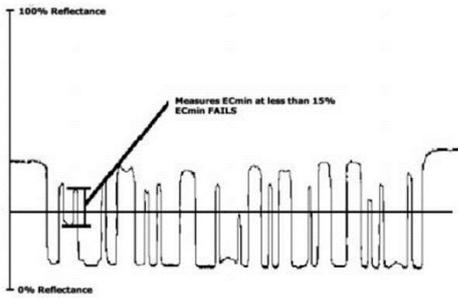
Fig. 21: Minimum edge contrast (Fail) [26]

2.4) Symbol Contrast or SC (Graded) is the value that represents how much the difference between R_{max} and R_{min} The higher the value, the better in reading quality. The grading levels are categorized by Eq. (8). Examples of Grade A and F for SC are illustrated in Fig. 22 and 23, respectively.

$$SC = R_{max} - R_{min} \qquad (8)$$

; where $\qquad$ SC ≥ 70% equal to grade A or 4

$\qquad\qquad\qquad$ SC ≥ 55% equal to grade B or 3

$\qquad\qquad\qquad$ SC ≥ 40% equal to grade C or 2

$\qquad\qquad\qquad$ SC ≥ 20% equal to grade D or 1

$\qquad\qquad\qquad$ SC < 20% equal to grade F or 0
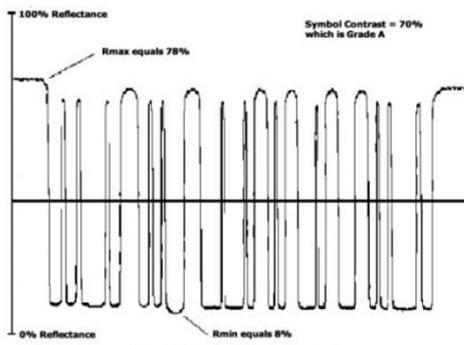
Fig. 22 Example the grade A or 4 for Symbol Contrast [26]
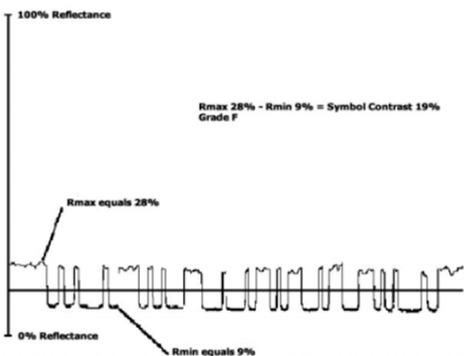
Fig. 23 Example the grade F or 0 for Symbol Contrast [26]

2.5) Modulation, MOD (Graded) is the parameter to measure the consistency of light reflection distribution for the space and bar, which could be calculated by using Edge contrast minimum, EC_{min} and Symbol contrast (SC); where MOD ≥ 0.70 is the grade for A or 4, ≥ 0.60 for B or 3; ≥ 0.50 for C or 2; ≥ 0.40 for D or 1 and MOD < 0.40 for F or 0. Fig 24 and Fig 25 show example of the grade A and F for the MOD, respectively.
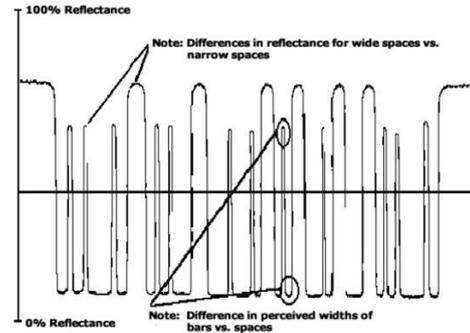
Fig. 24 Example for Modulation with the grade A or 4 [26]
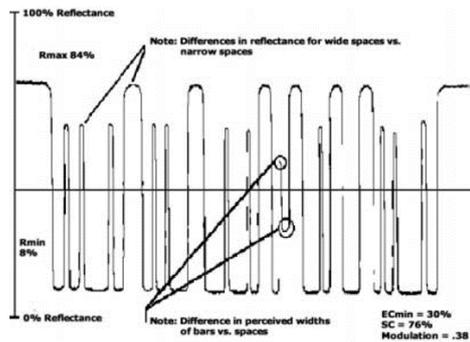
Fig. 25 Example for Modulation with the grade F or 0 [26]

2.6) Defects (Graded) are the abnormal occurrences found from the light that reflects from the bar or the space. The Defects can be determined from the ratio between the Element Reflectance Non-uniformity, ERN_{max} and Symbol Contrast (SC); where Defects ≤ 0.15 refers to the grade A or 4; ≤ 0.20 to the grade B or 3; ≤ 0.25 to the grade C or 2; ≤ 0.30 to the grade D or 1 and < 0.30 to the grade F or 0. The examples of the grade A and F for the Defects are shown in Fig. 26 and Fig. 27, respectively.

Fig. 26 Example for Defects with the grade A or 4 [26]

Fig. 27 Example for Defects with the grade F or 0 [26]

2.7) Decodability (Graded) is the capability of decoding the barcode. In other words, it is the precision of the printed barcode and the decoding algorithm.

2.8) Decode (Pass/Fail) is the barcode decoding using the standard algorithm (AIM, ANSI, CEN, ISO)

2.9) Quiet zones are the space areas on the left and right of the barcode. These areas must be clear [26].

Fig. 28 and Fig. 29 show the process of the system operation, which could be summarized as follows:

- User selects the style of the master packaging box (no. 1 in Fig.9).

- Place the master pack in the location where the image will be captured. Then press the start button, the status light of the selected pattern will be on (no.2).

- NI Vision builder automated inspection (VBAI) program processes images and displays them on the screen (no.3).

- The system will display the barcode reading result (no. 4), the Pass/Fail status in the system barcode reading (no. 5), the number of packages with the Pass status (green), Fail (red), the total number of tests and Accuracy percentage of barcode reading on the Master pack (no. 6)

- The system sends the barcode data to the database and exits.

Fig. 28 display screen of the designed program

Fig. 29 Operating diagram of a barcode reading system using image processing

- While the image processing system, the operation window will show Processing status (yellow color) and when finished, it will display Ready status (green) as shown in Fig.28 and when a malfunction can the Refresh button (no. 8).

The diagram that demonstrates how the NI Vision program operates is shown in Fig.30; where there are the arrow lines that show the start and end step. Each line has its own constrain that differs from others. In some cases, there are some middle lines (default) that are the signs for the program to repeat the running while checking the status first before processing the next step(s).

Fig. 30 Diagram of NI Vision builder automated inspection (VBAI)

2.2 Experimental Design

The experimental scenarios were conducted for barcode decoding of NI Vision builder automated inspection (VBAI) program to test the accuracy and completeness of the proposed barcode verification. The following method was developed:

1) Use a master pack with accessories inside the master pack with 10 phone boxes and 20 boxes.

2) Use the watch to time the program barcode decoding per 1 Master pack.

3) Repeat the test for all the 3 variants as detailed in Table 1.

	Group 1	Group 2	Group 3
Variant Name	Variant A2	Variant K1	Variant S1
Information of the Master Box			
- Size (in cm.)	19x 29 x19	15 x 47 x 19	15 x 47 x 19
- number of boxes	50	25	25
- number of mobile boxes	10	20	20
Information of the Barcode			
- Type	Code 128	Code 128 / EAN 13	Data matrix / EAN 13
- Size (in cm.)	3.5 x 0.5	3.5x 0.5 / 2.5x 0.5	0.5x 0.5 / 2.5x 0.5
- number of barcode/box	10	20 / 20	20 / 20
Total	**500**	**500 / 500**	**500 / 500**

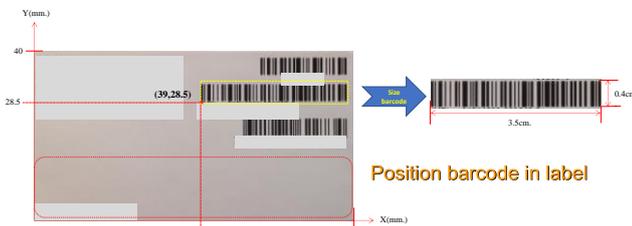**Table 1** Details of each packaging group of all the 3 sample groups

Fig. 31 An example for barcode's position and size
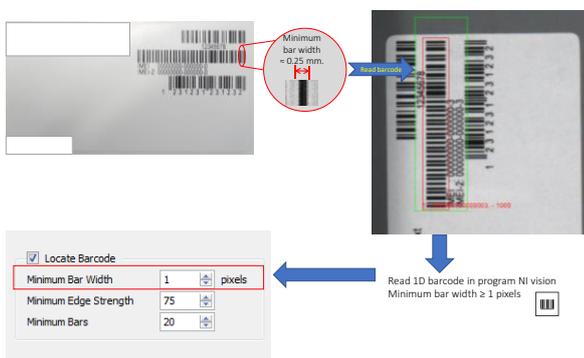

Fig. 32 Example of fundamental NI Vision steps

Check the running status of the program (Pass/Fail) can calculate errors. To find the accuracy (Accuracy) using the following equation.

$$\text{Relative error} = \frac{|\alpha - \beta|}{|\alpha|} \qquad (9)$$

; where α is the number of experimental barcodes and β is the number of readable barcodes (Pass) [27-28].

4) Compare working time (Barcode decoding) from legacy (barcode decoding using scanners) and barcode decoding system using image processing. By applying appropriate statistical principles

3. Results and Discussion

Tables 2- 5 shows the information of the test samples (variants) and their testing results. There were 4 groups of the variants: Variant A2, Variant K1 (for Code 128), Variant K1 (for EAN13) and Variant S1. The results in terms of the repeating tests for 25 times, point value of 1,000 points and Grade for each testing barcode were recorded.

Variant A2			
Barcode Sequence	Status Pass (50 Times)	Points value (1,000 Points)	Grade Barcode
1	47	1,000	3.33
2	47	1,000	3.34
3	44	993.03	2.86
4	48	995.36	3.34
5	49	1,000	3.42
6	50	1,000	3.77
7	50	1,000	3.73
8	50	997.91	3.31
9	49	1,000	3.63
10	49	1,000	3.65
Average	**48.30**	**998.63**	**3.44**

Table 2 Results of groups 1 (Variant A2)

Variant K1 for Code 128			
Barcode sequence	Status Pass (25 Times)	Points value (1,000 Points)	Grade Barcode
1	25	1,000	3.06
2	25	1,000	2.95
3	25	1,000	3.07
4	25	1,000	3.06
5	25	1,000	2.80
6	25	995.82	2.84
7	25	1,000	2.96
8	25	1,000	2.96
9	25	1,000	2.96
10	25	1,000	2.68
11	24	1,000	2.62
12	25	1,000	2.95
13	24	1,000	2.97
14	23	1,000	2.94
15	25	1,000	2.94
16	25	1,000	2.94
17	25	1,000	3.01
18	25	1,000	2.83
19	25	1,000	2.66
20	25	1,000	2.99
Average	**24.8**	**999.8**	**2.91**

Table 3 Results of groups 2 (Variant K1) for code 128

Variant K1 for Code EAN 13			
Barcode sequence	Status Pass (25 Times)	Points value (1,000 Points)	Grade Barcode
1	25	848.12	2.98
2	25	848.12	2.98
3	25	848.12	2.96
4	25	848.12	2.93
5	25	848.12	2.93
6	25	848.12	2.93
7	25	848.12	2.93
8	25	848.12	2.93
9	25	847.39	2.93
10	25	847.40	2.86
11	25	848.12	2.87
12	25	848.12	2.94
13	25	848.12	2.94
14	25	848.12	2.94
15	25	848.12	2.94
16	25	848.12	2.94
17	25	848.12	2.91
18	25	848.12	2.82
19	25	848.12	2.81
20	25	848.12	2.88
Average	25	848.1	2.92

Table 4 Results of groups 2 (Variant K1) for code EAN 13

Variant S1				
Barcode sequence	Status of Data Matrix Pass (25 Times)	Status of EAN 13 Pass (25 Times)	Points value (854.20 Points)	Grade Barcode
1	25	25	848.12	3.20
2	23	25	848.12	3.20
3	24	25	848.12	3.19
4	25	25	848.12	3.19
5	24	25	848.12	3.18
6	25	25	848.12	3.19
7	25	25	848.12	3.17
8	25	25	848.12	3.14
9	24	25	848.12	3.11
10	25	25	848.12	2.94
11	24	25	848.12	3.04
12	24	25	848.12	3.14
13	24	25	854.20	3.16
14	25	25	848.12	3.17
15	24	25	854.20	3.17
16	23	25	848.12	3.15
17	25	25	848.12	3.10
18	24	25	846.68	3.06
19	24	25	848.12	3.06
20	25	25	848.12	3.06
Average	24.35	25	848.66	3.20

Table 5 Results of groups 3 (Variant S1)

It is noted that the scores shown in Table 2-5 are the score for the barcode and grade of the barcode based on the standard barcodes (AIM, ANSI, CEN, ISO) evaluations. There were 9 parameters used for the evaluation, which were Edge determination grade, Minimum reflectance grade, Minimum edge contrast grade, Symbol contrast grade, Modulation grade, Defects grade, Decode grade, Decodability grade and Quiet zone as afore-explanation. The grading could be equivalent to the Master pack barcode used in this research as shown in Fig. 33.

Alphabetic grade	Numeric grade (average)
A	3.5 to 4.0
B	2.5 to just less than 3.5
C	1.5 to just less than 2.5
D	0.5 to just less than 1.5
F	Less than 0.5

Fig. 33 Grading for the Master pack barcode [26]

Based on the error data and the time spent by the worker using the handy scanner to scan the barcodes of the master pack and the experimental results of the three sample groups according to Table 1, the results were analyzed into 2 aspects: accuracy of barcode reading and barcode reading time. The details are as follows:

3.1 Accuracy of Reading Barcodes

Fig. 34, 35 and 36 show the photographs of the display screens when barcode scanning and reading results were Pass or Fail when testing the sample set 1 (variant A2), 2 (variant K1) and 3 (variant S1), respectively. When considering the accuracy data for scanning the barcode inside the worker's packaging box using the handy scanner, it was found that the average accuracy of the sample set 1 (variant A2), 2 (variant K1), 3 (variant S1) and overall were 93%, 88.70%, 96.70%, and 94.04%, respectively. In turn, when using the proposed technique by image processing of all 3 samples above, it was found that the average accuracy of the sample set 1 (variant A2), 2 (variant K1), 3 (variant S1) and overall were 96.60%, 99.60%, 98.70%, and 98.64%, respectively.

Fig. 37 shows graph of the comparison of the accuracy of barcode reading using the proposed image processing system and legacy system.
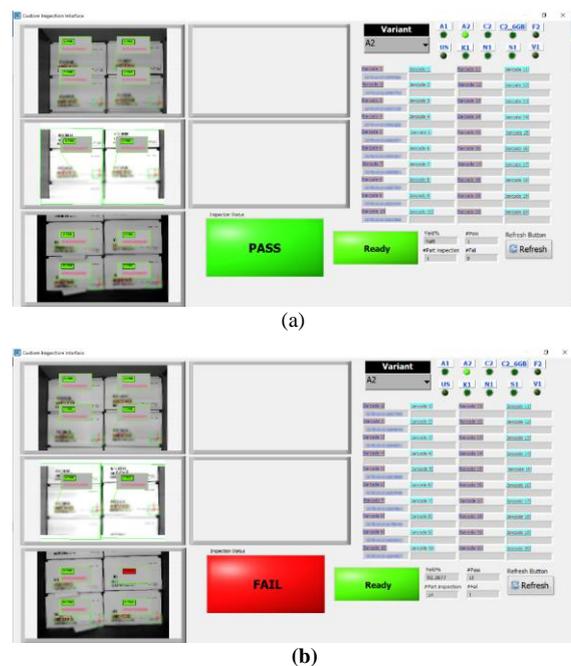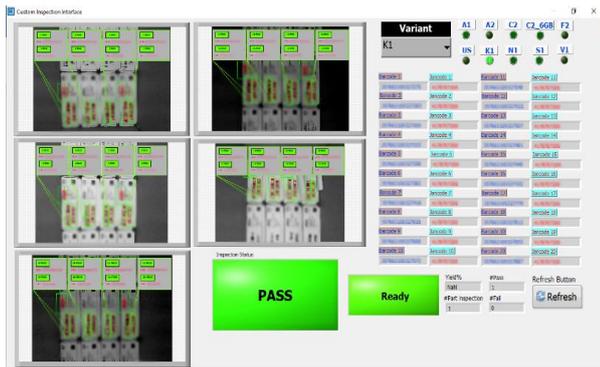

(a)

(b)

Fig. 34 Show sample picture of experimental results of sample 1 (Variant A2), a) in case of reading barcode Pass, b) in case of reading Barcode Fail (This image is retouched blurry due to a trade secret)
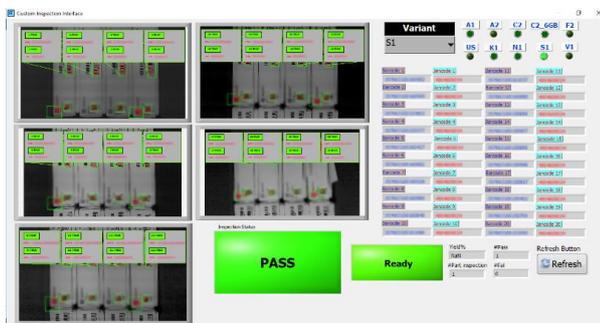
(a)

(b)

Fig. 35 Show sample picture of experimental results of sample 2 (Variant K1), a) in case of reading barcode Pass, b) in case of reading Barcode Fail

(a)

(b)

Fig. 36 Show sample picture of experimental results of sample 3 (Variant S1), a) in case of reading barcode Pass, b) in case of reading Barcode Fail. (This image is retouched blurry due to a trade secret)
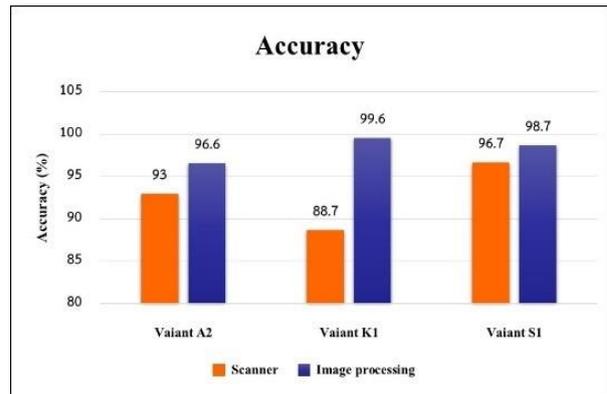

Fig. 37 A graph that compares the accuracy of barcode reading using image processing and legacy systems

3.2 Time Spent for Reading Barcodes

Based on data on the time used for operator using the scanner to scan the barcode on the master pack and the timing of the bar reading trial by image processing, From the three sample groups, it was found that the workers spent time scanning barcodes in sample 1 (Variant A2), in sample 2 (Variant K1) and in sample 3 (Variant S1) on average 19.03, 54.80 and 71.22 second, respectively. For reading barcodes by image processing, the average barcode reading time was 6.41, 12.94 and 11.59 seconds, respectively. Fig. 38 shows the graph of the time it takes to read the barcode compared to the old system.
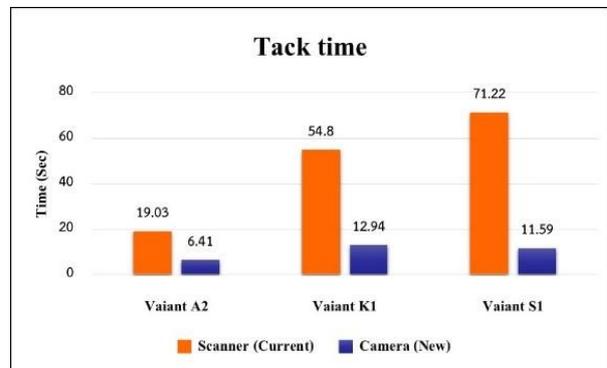

Fig. 38 The graph of the time it takes to read the barcode compared to the old system

4. Conclusions

This research proposes a multiple-barcode verification using the commonly used NI Vision image processing program for mobile phone packaging process. The verification system consists of cameras with a lighter and a NI Vision 2018 image processing program. The program reads 8-20 barcodes at a time from a photograph captured by the fixed-position camera. The average accuracy of barcode scanning by the manual operator was 94.04%, while the accuracy of reading barcodes by image processing was 98.64%. So it can be concluded that the proposed technique provides more accurate than

conventional manual scanning, by 4.60%, so workers' barcode scanning errors can be reduced using scanners like I. Zafar [9] and Abahan Sarkar [29]. Image processing techniques can be used to increase the accuracy of inspection of barcodes and end labels. However, different types of barcodes result in different barcode reading accuracy.

In addition, the proposed technique could reduce the barcode scanning time to 6.41–12.94 seconds from 19.03–71.22 seconds, or reduce the time to approximately 3-6 times that of the previous system.

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Biographies

Phakamat Mingkhwan was born in July 5, 1995, at Bueng kan, Thailand. She received her Bachelor degree in Electrical Engineering from Mahasarakham University in 2018, continued her Master degree in Electrical and Computer Engineering, Mahasarakham University, Thailand, under the scholarship of the Work Integrated Learning (WIL) while working at Sony Technology (Thailand) Co., Ltd, Thailand. She is currently working at Eastern Technical Engineering Public Co., Ltd., Thailand.

Sarinya Sala-ngam received her B.Eng. from Nihon University, Japan in 2011. She received her M.Eng. and Ph.D. in Industrial Engineering and Management from Nihon University, Japan, in 2013 and 2017, respectively. She is currently an associate director of Mahasarakham University-Industry Cooperation Center, Mahasarakham University, Thailand, and a lecturer in Manufacturing Engineering, Faculty of Engineering, Mahasarakham University, Thailand. Her research interests include industrial engineering and management.

Alongkorn Lamom received his B.Eng. and M.Eng. in Civil Engineering from Suranaree University of Technology, Thailand, in 1995. He received his Ph.D. in Computer Engineering from Chulalongkorn University, Thailand, in 2014. He is currently an assistant professor at the Faculty of Engineering, Mahasarakham University, Thailand. He is the member of IEEE-Industrial Society. His research interests include civil engineering and computer programing and application.

Krittanon Prathepha received his B.Eng. in Electrical Engineering from Kasetsart University, Thailand in 2013. He received his M.Eng. in Electrical and Computer Engineering from Mahasarakham University, Thailand in 2017. He is currently a lecturer in electrical engineering at the Faculty of Engineering, Mahasarakham University, Thailand. His research interests include thermoelectric applications, electrical and electronic engineering.

Chonlatee Photong received his B.Eng. from Khon Kaen University, Thailand in 2001. He has been worked at Sony Device Technology (Thailand) Co., Ltd. and Seagate Technology (Thailand) Co., Ltd. for 3 and 2 years, respectively. He received his M.Sc. in Power Electronics and Drives and Ph.D. in Electrical and Electronic Engineering from University of Nottingham, UK, in 2007 and 2013, respectively. He is currently the bachelor program director of Practical Engineering (Continuing Program) and a lecturer in Power Electronics and Drives at the Faculty of Engineering, Mahasarakham University, Thailand. He is the member of IEEE-Industrial Society. His research interests include power electronics, power converters for renewable energy conversion, and electrical machines and drives.