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Performance Evaluation of Automatic Number Plate Recognition on Android Smartphone Platform

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ABSTRACT

Automatic Number Plate Recognition (ANPR) is an intelligent system which has the capability to recognize the character on vehicle number plate. Previous researches implemented ANPR system on personal computer (PC) with high resolution camera and high computational capability. On the other hand, not many researches have been conducted on the design and implementation of ANPR in smartphone platforms which has limited camera resolution and processing speed. In this paper, various steps to optimize ANPR, including pre-processing, segmentation, and optical character recognition (OCR) using artificial neural network (ANN) and template matching, were described. The proposed ANPR algorithm was based on Tesseract and Leptonica libraries. For comparison purpose, the template matching based OCR will be compared to ANN based OCR. Performance of the proposed algorithm was evaluated on the developed Malaysian number plates' image database captured by smartphone's camera. Results showed that the accuracy and processing time of the proposed algorithm using template matching was 97.5% and 1.13 seconds, respectively. On the other hand, the traditional algorithm using template matching only obtained 83.7% recognition rate with 0.98 second processing time. It shows that our proposed ANPR algorithm improved the recognition rate with negligible additional processing time.

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1. INTRODUCTION

Due to the increasing number of vehicle nowadays, the modern city needs to establish the effective and efficient automatic traffic system for the management of the traffic law enforcement. Automatic number plate recognition (ANPR) leads the significant role in this condition. The ANPR is an image processing technique to extract the image of license plate on vehicle taken by digital camera or taken by either a color or a grayscale digital camera, as well as an infrared camera in order to identify the vehicles using their number plate through optical character recognition (OCR) [1].

The ANPR system recognizes characters on license plate through the combination of various techniques and algorithms, including image pre-processing, object detection, character segmentation and recognition. It consists of a camera to detect the number plate object and processing unit to process and extract the characters and interpret the pixels into numerically readable characters [2]. It became much exciting in the last decade along with the improvement of digital camera technology and the computational processing [3]. Nowadays, the ANPR system has been used in traffic law enforcement, including speed camera, traffic light camera, stolen car detection, and border monitoring. It can be used also for the building management, such as parking management and gate control [4], [5].

Android smartphone operating system (OS) has captured more than 82% of the total market-share as of 2015 [6]. Android is the most popular mobile operating system due to its open architecture and the popularity of its application programming interface (APIs) in the developer community. Due to its open source nature, Android OS can be found from low end device to the high end device. Android can be divided into roughly three layers below the application layer, including the application framework layer, the runtime and libraries layer, and the kernel layer. The proposed ANPR system was implemented in the application framework layer.

Although many researches have been conducted on the ANPR system. However, the implementation platform is normally a high resolution camera with high computing power and not many researches have been conducted on the ANPR implementation on the smartphone with lower resolution camera and lower computing power. Therefore, the objective of this paper is to proposed ANPR system implemented on Android smartphone and to evaluate its performance in recognizing Malaysian number plate. The design of the ANPR system, including GUI design, process design, and database design on Android platform has been presented in [7], while this paper will focus on the performance evaluation of the proposed ANPR system. The rest of the paper is organized as follows. Section 2 introduces the proposed ANPR system, with the improvement or enhancement to the original ANPR algorithm by Tesseract [8]. Section 3 discusses the implementation and construction of Malaysian number plate image database. Section 4 evaluates performance of the proposed algorithm compared to the original algorithm [8], while Section 5 concludes the paper.

2. PROPOSED ANPR ALGORITHM

The ANPR system generally consisted of the following five stages [9] as shown in Figure 1. The first stage is image acquisition, capturing the image of license plate using a camera by considering the camera resolution, orientation, shutter speed and light. The second stage is image pre-processing, such as normalization, brightness and contrast adjustment, and skewness correction of the captured image. The third stage is localizing the license plate to extract the license plate from the whole vehicle image based on some features, such as the boundary, the color, or the presence of the characters. The fourth stage is character segmentation to segment the characters on the license plate by locating and identifying the individual character on the license plate image. The final stage is optical character recognition to recognize the segmented characters by pattern matching or classifiers, such as artificial neural networks (ANN), fuzzy logic, Hidden Markov Model (HMM), template matching [10]. The ANPR system can be connected to other applications or databases to further enhance its functionality.

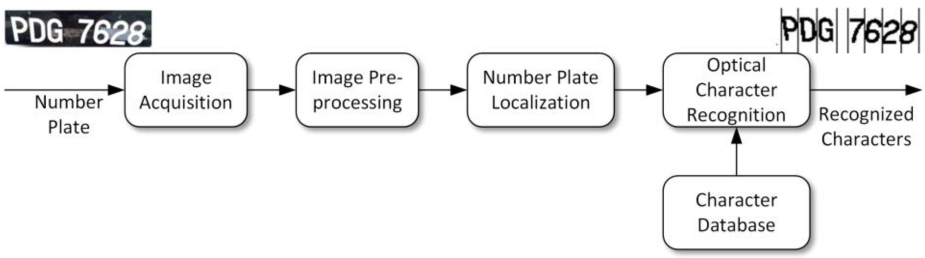

Figure 1. Typical ANPR System.

Based on previous design presented in [7], the proposed algorithm can be illustrated in Figure 2. It shows the difference between the original ANPR algorithm developed by [8] and our proposed ANPR system. Note that, the original algorithm was developed mainly for optical character recognition which can recognize various alphanumeric characters. The input image is acquired using Android smartphone's camera which has low resolution. The noticeable difference can be found in the image preprocessing stage. We add several enhancements, including edge enhancement using unsharp masking, color inversion, and Otsu thresholding with fraction of 0.1. The performance improvement by adding additional unsharp masking and color inversion will be further explored in Section 4. Meanwhile, fixed pitch detection and chopping was used in the character segmentation stage, while ANN or template matching was utilized in the OCR stage.

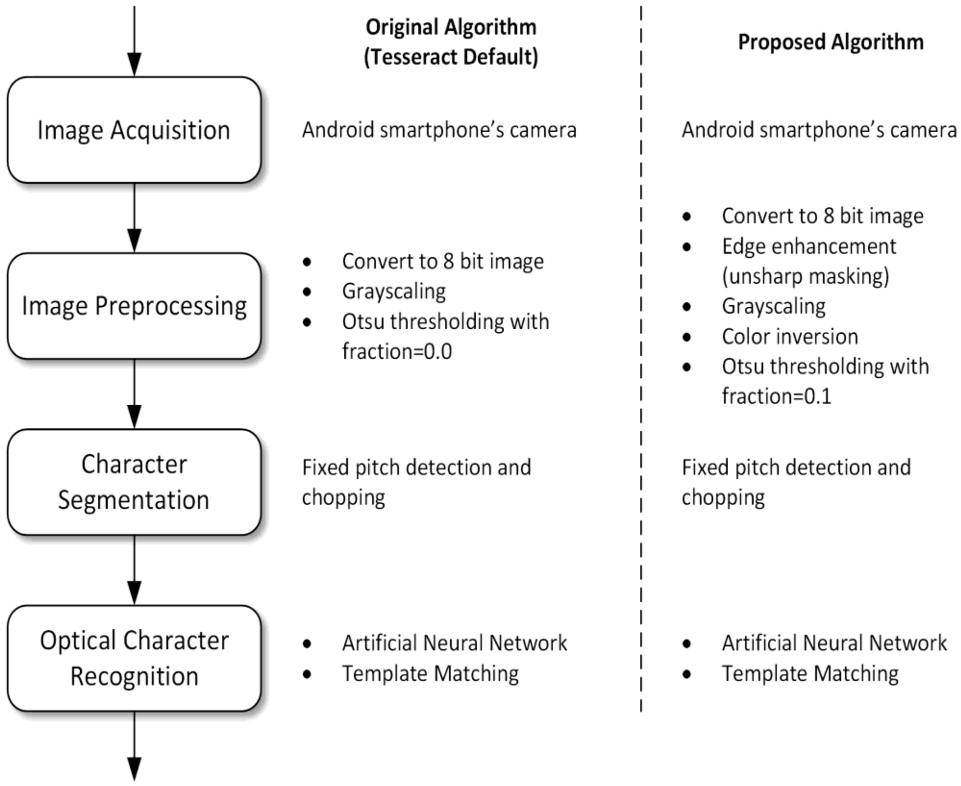

Figure 2. Original ANPR Algorithm [8] versus Proposed Algorithm.

3. IMPLEMENTATION OF ANPR ALGORITHM

In this section, the implementation of ANPR algorithm on Android smartphone will be discussed. First, the actual graphical user interfaces (GUI) for the ANPR system on Android smartphone was constructed based on the GUI design as described in [7]. The hardware specification of Android smartphone used will be described. Finally, the Malaysian number plate image database was constructed, including 15 one row and 15 two rows number plate types.

3.1. Software and GUI implementation

For the software implementation, the Leptonica library will be used to implement image processing algorithm [11], while Tesseract library will be used as the core engine for OCR [8]. Leptonica is an open source C library which is useful for efficient image processing and image analysis applications. The library is developed since 2001 by a Google employee, Dan Bloomberg, and it is licensed under a Creative Commons Attribution 3.0 United States License. For the purposed of obtaining a better image quality, some function of Leptonica library are used in this research. On the other hand, Tesseract was developed between 1985 and 1994 at Hewlett Packard Laboratories Bristol and Hewlett Packard Co, Greeley Colorado. It appeared for the first time in 1995 at University of Nevada Las Vegas (UNLV) Annual Test of OCR Accuracy. It was a PhD research project conducted in HP Labs, Bristol, and it had the momentum as a possible software and hardware add-on for the HP's line of flatbed scanners. After ten years, due to lacking any further development, HP released the Tesseract as open source in late 2005. Note that, both Leptonica and Tesseract were not native Android library, so the Android SDK need to be configured properly to use the functions in the libraries.

For the GUI implementation, the actual ANPR GUI for Android smartphone is shown in Figure 3. The actual GUI contains four main menus including camera menu, map menu, manual input menu, and searching menu. The main page shows the list of number plates along with the date taken in the right side of the number plate. The GPS coordinate is related to the Google map to show the actual location. Furthermore, there is one screenshot of email notification from the server informing the number plate recognized by the Android ANPR system. Note that, the GUI design, process design and database design was explained in [7]. The actual GUI illustrated a law enforcement scenario, where a police captured the wrongly park vehicle number plate, in which the system later on sends the notification email to the owner of the vehicle.

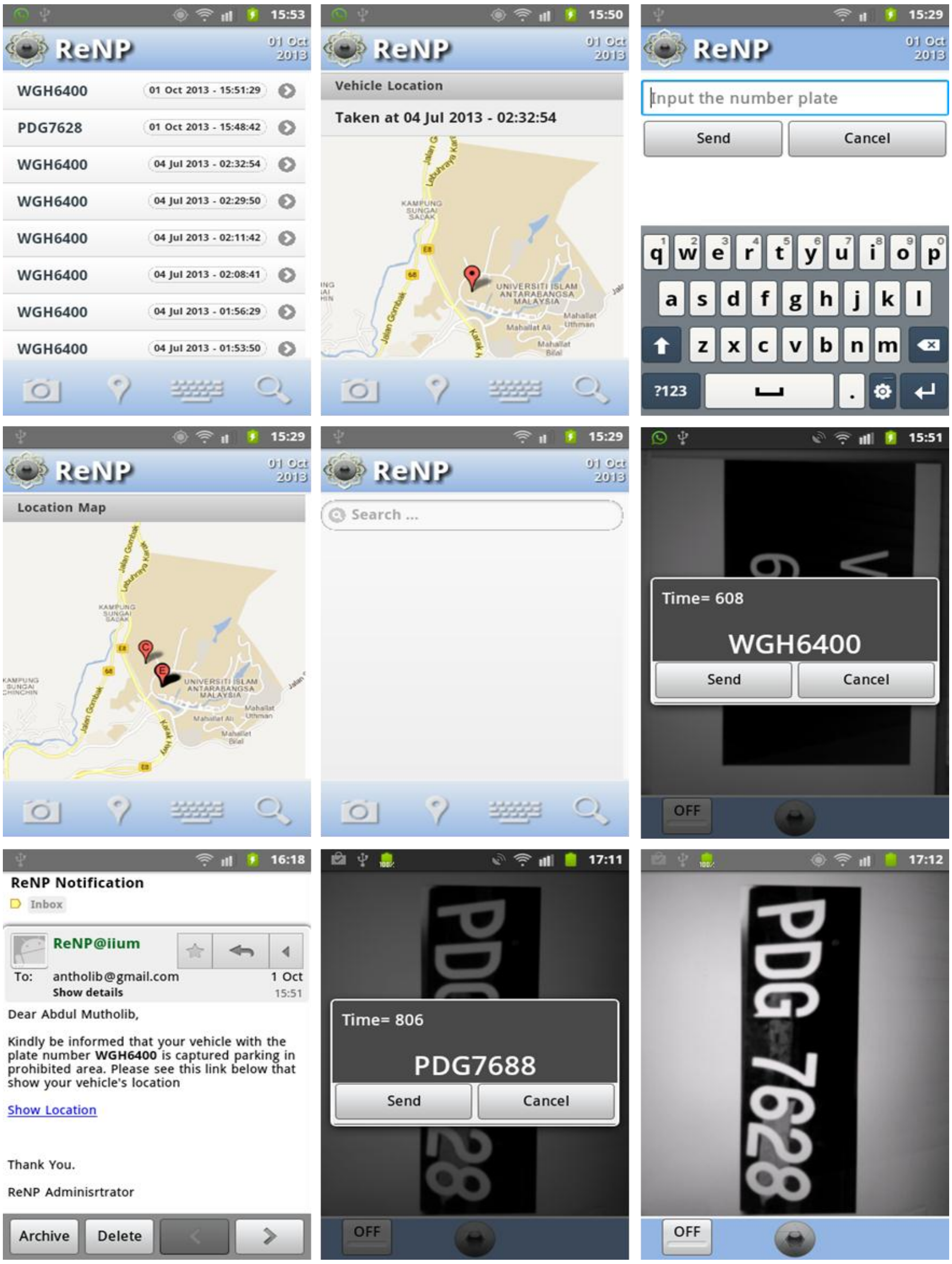

Figure 3. Actual Graphical User Interface (GUI) of the Proposed ANPR System.

3.2. Hardware Implementation

The Android mobile phone used in this research is Samsung GT-S5830 known as Galaxy Ace or Galaxy Cooper which is mid-end smart phone family released by Samsung in February 2011. It has 800 MHz 1 Core ARM v6 of processor with 278.34 MB of RAM. The screen resolution is HVGA (480 x 320) ~165 ppi pixel density and 5 mega pixels of camera resolution. This Android mobile phone model is installed Android OS version 2.3. The requirement in this research is the Android version should be 2.3 or later and should have camera.

3.3. Malaysian Number Plate Image Database

For the purpose of the research, it required to set up the experimental data of the number plates images which were taken under various time and condition. In this research, the image database are divided into two groups of Malaysian vehicle number plates. First group is one row number plates as shown in

Figure 4 (number 1 to 15). Second group is two rows number plates as shown in Figure 4 (number 16 to 30). The one row number plate is normally used in car, while the two rows number plate is normally used in motorcycle.

(a)

(b)

Figure 4. Samples of Malaysian Plate Number, (a) One row (1 to 15), (b) Two rows (16 to 30).

4. RESULTS AND DISCUSSION

In this section, the performance evaluation of the proposed ANPR system implemented on Android smartphone will be elaborated. First, the performance measures were discussed, including the accuracy or recognition rate and the processing time. Next, the effect of unsharp masking and color inversion was explored. Lastly, the performance comparison between original Tesseract OCR algorithm and the proposed ANPR system using either ANN or template matching was discussed in more details.

4.1. Performance Measures

In this research, the method to measure accuracy of recognition rate is based on the objective evaluation as in [12]. The number of error can be defined as the total characters to be recognized subtracted with the characters that do not match with the correct character or original character, such as character insertion, deletion and substitution. If there are *n* total characters to be recognized, then the accuracy is stated as [12]:

$$Accuracy = \frac{n - \#errors}{n} \times 100\% \quad (1)$$

The processing time in millisecond was also recorded in our experiments. Additional complexity will be justified if the additional computational time is negligible.

4.2. The Effect of Unsharp Masking and Color Inversion

As shown in Figure 2, the proposed ANPR system includes additional algorithms, including edge enhancement (unsharp masking) and color inversion (negative image). Unsharp masking was used to sharpen the number plate image, while the color inversion was used to reverse the color of alphanumerical characters with its background. Both algorithms reduce some noises produces during the image acquisition step so that it will be better recognized by the next stage. Furthermore, the Otsu method was set with fraction parameter value of 0.1. For the testing purposes, template matching algorithm was utilized in the OCR stage. Table 1 shows the results in terms of processing time (ms) and accuracy (%) for the proposed ANPR system without unsharp masking, without color inversion, and without both unsharp masking and color inversion.

Table 1. The Effect of Unsharp Masking and Color Inversion to the Accuracy and Processing Time

No	Number Plate	Without Unsharp Masking			Without Color Inversion			Without Unsharp Masking and Color Inversion		
		Output	Time (ms)	Acc. (%)	Output	Time (ms)	Acc. (%)	Output	Time (ms)	Acc. (%)
1	WAX5739	WAX573S	1512	57.1	-	887	0.0	X5739	972	71.4
2	PDG7628	PUG7628	809	85.7	XDGJEBB	1043	28.6	EDS76	934	42.9
3	BFP2569	BFP2569	647	100.0	BFP2569	706	100.0	BFP2569	766	100.0
4	WGA2761	WGA2781	1008	85.7	VIGA2761	770	85.7	VIGA2761	844	85.7
5	MAH8015	MAH8015	878	100.0	RAINBOWS	1397	14.3	MINEMS	1001	14.3
6	MCH929	MCH929	711	100.0	M03929	1324	66.7	NOISES	1143	0.0
7	WRF5851	WRF5851	768	100.0	VMA	741	0.0	VMA	888	0.0
8	CBS1300	CBS1300	943	100.0	CBS130	1237	85.7	CBS1305	1098	85.7
9	MAP5384	HAP5384	865	85.7	MAP53871	803	85.7	MAP538I	777	100.0
10	WNM344	WNM3M	796	66.7	WNM344	822	100.0	WNM344	872	100.0
11	CBT4465	CBT4465	928	100.0	CBT4465	1233	100.0	CBT4465	2228	100.0
12	WVV7054	WVV7054	833	100.0	WVV7054	1021	100.0	WVVIROSA	868	42.9
13	MBG127	MBG127	753	100.0	MB127	3319	83.3	M36127	2187	66.7
14	WGQ6464	WGQ6464	1068	100.0	WGQV6LL64	1592	71.4	WGQ6464	1033	100.0
15	WUT4251	NUT4251	1237	85.7	ILUT4251	1048	85.7	INN4251	1103	57.1
16	BJW3236	BJW322E	1635	71.4	2238I	1172	0.0	-	572	0.0
17	WGQ7921	WGQ7921	1271	100.0	WGQ7921	940	100.0	WGQ7921	891	100.0
18	KCM4303	KCM4303	992	100.0	KCMA4303	1560	100.0	KCN4303	868	85.7
19	WPM9605	WPM9605	927	100.0	WPM	545	42.9	WPM	625	42.9
20	PKA4220	PKA4220	762	100.0	PKA4220	946	100.0	PKA4220	1462	100.0
21	BEN3688	BENT3688	820	100.0	BENY3688	723	85.7	BENY3688	704	85.7
22	DBP8757	DBP8757	1025	100.0	-	481	0.0	NAPB757	896	57.1
23	WDG292	WDCI1292	1355	66.7	TFNNCI1292	1055	50.0	INCI1292	1012	50.0
24	WDB6306	WDB6306	778	100.0	7WDBE306	1309	85.7	-	468	0.0
25	WPN1674	WPN1674	804	100.0	-	462	0.0	-	445	0.0
26	WGF8459	WGF8459	1109	100.0	WGFE459	1060	57.1	WEE459	1343	57.1
27	WNX7895	WNX7895	716	100.0	-	466	0.0	-	442	0.0
28	AFW7480	AW1480	1229	71.4	AFN7480	825	85.7	AFV7480	806	85.7
29	ABS1544	ABS1544	870	100.0	ABS1544	856	100.0	ABS1544	694	100.0
30	WWW8946	8946	751	57.1	-	476	0.0	-	448	0.0
	Average		960	91.1		1027	60.5		946	57.7

Table 1 shows that the average accuracy of the proposed ANPR system without unsharp masking, without color inversion, and without both algorithms are 91.1%, 60.5%, and 57.7%, respectively. The processing time for each scenario are 960, 1027, and 946, respectively. Note that, the accuracy and the processing time for the proposed ANPR system with template matching are 97.5% and 1136.5 ms, respectively, as will be discussed later in Table 5. The results showed that unsharp masking has positive effect and the color inversion has significant effect on the accuracy, while adding negligible additional processing time. It can be concluded that the combination of both unsharp masking and color inversion algorithms have significant contribution to the proposed ANPR system.

4.3. Performance of ANPR Algorithms with ANN

In this section, the original algorithm used the default parameters in Tesseract library [8] without modification, optimization, or inclusion of additional processes (see Figure 2). Both the original algorithm and proposed ANPR system used ANN in the OCR stage. Table 2 shows the performance comparison between original ANPR algorithm with the proposed ANPR system for both one row and two rows Malaysian number plate, in terms of accuracy and processing time.

Table 2. Accuracy and Processing Time of ANPR Algorithms using ANN for One Row (1-15) and Two Rows (16-30) Malaysian Number Plates

No	Number Plate	Original Tesseract Algorithm			Proposed ANPR Algorithm		
		Output	Time (ms)	Acc. (%)	Output	Time (ms)	Acc. (%)
1	WAX5739	-	38206	0.0	TTHY5739	41341	57.1
2	PDG7628	-	37184	0.0	POLL7828	59168	57.1
3	BFP2569	BFP2569	50495	100.0	BF2569	52213	85.7
4	WGA2761	H276F	38625	42.9	TI312781	39872	42.9
5	MAH8015	LL8015	49578	57.1	1KHLL8015	44102	71.4
6	MCH929	KLL929	46809	50.0	LL0HL929	63921	66.7
7	WRF5851	ITIER585N	48283	42.9	WF5851	39073	85.7
8	CBS1300	CTS1300	52343	85.7	C891300	50839	71.4
9	MAP5384	LIHP538D	49887	57.1	HH5384	55822	57.1
10	WNM344	LLMD	42901	0.0	TINI43TL4	37134	50.0
11	CBT4465	CBTMTH	40858	42.9	CBT4485	51112	100.0
12	WVV7054	TILLY7054	50515	57.1	TILLL7054	45404	57.1
13	MBG127	TIIBTIT27	43781	50.0	TTIIYIT27	51237	33.3
14	WGQ6464	M30TM64	52508	28.6	TTIMIYL64	52500	28.6
15	WUT4251	TITRRTL25F	49803	42.9	JIITYF625F	41316	28.6
	Average		46118.4	43.8		48336.9	59.5
16	BJW3236	BJIFLW3T3TITT	59340	57.1	BDLFI3F3T	54769	42.9
17	WGQ7921	ILIA7921	42515	57.1	ILAL7921	46890	57.1
18	KCM4303	KCWD303	57386	57.1	KCMWD3FY3	58606	71.4
19	WPM9605	RPMTIEIXI	60992	28.6	GLPMS6CE	68959	28.6
20	PKA4220	PKAJT220	52929	85.7	PKAD220	61233	85.7
21	BEN3688	BEN3688	45051	100.0	BEN3688	57650	100.0
22	DBP8757	IERR8757	59659	57.1	BB8757	50565	71.4
23	WDG292	JLILTIIJ92	57432	33.3	VLLLLLTT292	64434	50.0
24	WDB6306	ILL0B6306	52464	71.4	LLLDB6306	73644	85.7
25	WPN1674	1EPRT1674	54346	71.4	GGDN167D	71637	57.1
26	WGF8459	HETYRJEE	56920	0.0	FR3FBD59	65902	42.9
27	WNX7895	LLINX7895	42514	71.4	1LLNX7895	49931	85.7
28	AFW7480	OHFLLIMM	53302	14.3	RHFLLR7480	56598	71.4
29	ABS1544	ABSISDD	49255	42.9	HBS15DD	54669	57.1
30	WWW8946	1LLLHILB9D6	67611	28.6	1LLLLLLLEB9D6	58551	28.6
	Average		54114.4	51.8		59602.5	62.4

It is noted that the result for one row number plates was significantly different to two rows number plates as can be seen in Table 2. It shows that the accuracy for two rows was better than one row number plate, in which the score was 51.8% compare to 43.8%. However, the processing time of two rows number plate is longer than one row number plates, i.e. 54.1 seconds and 46.1, respectively. The proposed ANPR system shows similar results, in which the accuracy is 62.4 and 59.5 for two rows and one row number plates, while the processing time is 59.6 and 48.3 seconds, respectively.

Table 3. Comparison between Original ANPR Algorithm and Proposed Algorithm using ANN

Number Plate	Original Tesseract Algorithm		Proposed ANPR Algorithm	
	Accuracy (%)	Processing Time (ms)	Accuracy (%)	Processing Time (ms)
One Row	43.8	46118.4	59.5	48336.9
Two Rows	51.8	54114.4	62.4	59602.5
Average	47.8	50116.4	61.0	53969.7

Table 3 focuses on the comparison between the original algorithm and the proposed algorithm in terms of accuracy and processing time. On average, the proposed ANPR algorithm increased the accuracy by 13.2% while additional processing time is only increased by 7.7%.

4.4. Performance of ANPR Algorithms with Template Matching

In this section, the original used the default parameters in Tesseract library [8] without modification, optimization, or inclusion of additional processes (see Figure 2). Both the original algorithm and proposed ANPR system used Template Matching in the OCR stage. Table 4 shows the performance comparison between original ANPR algorithm with the proposed ANPR system for both one row and two rows Malaysian number plate, in terms of accuracy and processing time.

Table 4. Accuracy and Processing Time of ANPR Algorithms using Template Matching for One Row (1-15) and Two Rows (16-30) Malaysian Number Plates

No	Number Plate	Original Tesseract Algorithm			Proposed Algorithm		
		Output	Time (ms)	Rate (%)	Output	Time (ms)	Rate (%)
1	WAX5739	-	1121	0.0	WAX5739	960	100.0
2	PDG7628	-	538	0.0	PDG7628	786	100.0
3	BFP2569	BFP2569	696	100.0	BFP2569	754	100.0
4	WGA2761	VIGA2761	3219	85.7	WGA2761	1120	100.0
5	MAH8015	MAH8015	830	100.0	MAH8015	996	100.0
6	MCH929	MCHS29	1263	83.3	MCH929	954	100.0
7	WRF5851	WKSS	1071	14.3	WRF5851	904	100.0
8	CBS1300	CBS1206	1016	71.4	CBSI300	972	85.7
9	MAP5384	MAP5382	805	100.0	HAP5384	908	85.7
10	WNM344	WNM344	812	100.0	WNM344	888	100.0
11	CBT4465	CBT4465	848	100.0	CBT4465	988	100.0
12	WVV7054	WVV7054	732	100.0	WVV7054	1157	100.0
13	MBG127	MBG127	679	100.0	MBG127	1765	100.0
14	WGQ6464	WGQ6464	1059	100.0	WGQ6464	1332	100.0
15	WUT4251	UT4251	837	85.7	WUT4251	1351	100.0
	Average		1035.1	76.0		1055.7	98.1
16	BJW3236	BJWF323S	1454	85.7	BJW322G	1585	100.0
17	WGQ7921	WGQ7921	963	100.0	WGQ7921	1327	100.0
18	KCM4303	KCM4303	883	100.0	KCM4303	1131	100.0
19	WPM9605	WPM9805	811	85.7	WPM9605	1023	100.0
20	PKA4220	PKA4220	668	100.0	PKA4220	1082	100.0
21	BEN3688	BENY3688	772	85.7	BEN3688	1315	100.0
22	DBP8757	DBP8757	862	100.0	DBP8757	914	100.0
23	WDG292	JIIDGI1292	1034	83.3	1FWDCI1292	1230	66.6
24	WDB6306	WDB6306	871	100.0	WDB6306	1131	100.0
25	WPN1674	QWPN1674	1189	85.7	WPN1674	1435	100.0
26	WGF8459	WSFJE459	1265	71.4	WGF8459	1304	100.0
27	WNX7895	NNX7895	632	85.7	WNX7895	890	100.0
28	AFW7480	AFW7480	816	100.0	AFW1480	1825	85.7
29	ABS1544	ABS1544	736	100.0	ABS1544	922	100.0
30	WWW8946	QWWW8946	790	85.7	WWW8946	1145	100.0
	Average		916.4	91.3		1217.3	96.8

It is noted that the result for one row number plates was significantly different to two rows number plates for original algorithm as can be seen in Table 4. It shows that the accuracy for two rows was better than one row number plate, in which the score was 91.3% compare to 76.0%. However, the processing time of two rows number plate is longer than one row number plates, i.e. 1.04 seconds and 0.92, respectively. The proposed ANPR system shows different results, in which the accuracy is 96.8 and 98.1 for two rows and one row number plates, while the processing time is 1.2 and 1.06 seconds, respectively. Table 5 focuses on the comparison between the original algorithm and the proposed algorithm in terms of accuracy and processing time. On average, the proposed ANPR algorithm increased the accuracy by 13.8% while additional processing time is only increased by 16.5%.

Table 5. Comparison between Original ANPR Algorithm and Proposed Algorithm using Template Matching

Number Plate	Original Tesseract Algorithm		Proposed ANPR Algorithm	
	Accuracy (%)	Processing Time (ms)	Accuracy (%)	Processing Time (ms)
One Row	76.0	1035.1	98.1	1055.7
Two Rows	91.3	916.4	96.8	1217.3
Average	83.7	975.8	97.5	1136.5

From Table 3 and Table 5, the results show that the accuracy for the proposed algorithm using ANN and Template Matching is 61.0 and 97.5, respectively. The processing time is 54.0 and 1.1 seconds, respectively. It can be concluded that the proposed ANPR system using template matching is better than using ANN. Therefore, template matching is more suitable to be utilized in ANPR system in Android smartphone due to its accuracy and lower computational time.

5. CONCLUSIONS AND FUTURE WORKS

The performance evaluation of proposed ANPR system implemented on Android smartphone platform has been presented. The original ANPR algorithm using Tesseract library was compared to the proposed ANPR system. The proposed ANPR system has additional processing steps, such as unsharp masking and color inversion. Results showed that our proposed ANPR system as higher accuracy with negligible additional processing requirement. On average, the proposed ANPR algorithm using ANN increased the accuracy by 13.2% while additional processing time is only increased by 7.7%. On average, the proposed ANPR algorithm using Template Matching increased the accuracy by 13.8% while additional processing time is only increased by 16.5%. Future works includes using higher resolution and higher processing smartphone, and improve the accuracy by adding additional enhancement algorithms.

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