Sensors and Materials, Vol. 31, No. 2 (2019) 287–292
MYU Tokyo

S & M 1769

Gel Documentation System Using an Open Platform Camera

Deuk-Ju Lee,[1,2] Yeo-Reum Kim,[1] Jong-Dae Kim,[1,2]
Yu-Seop Kim,[1,2] Hye-Jeong Song,[1,2] and Chan-Young Park[1,2*]

[1]Department of Convergence Software, Hallym University,
1, Hallimdaehak-gil, Chuncheon-si, Gangwon-do 24252, Republic of Korea
[2]Bio-IT Research Center, Hallym University,
1, Hallimdaehak-gil, Chuncheon-si, Gangwon-do 24252, Republic of Korea

(Received May 31, 2018; accepted October 31, 2018)

Keywords: gel documentation system, gel image analysis, DNA detection, fluorescence, open platform, IoT, smartphone camera

In general, DNA detection involves the following four steps: DNA extraction, DNA amplification, electrophoresis, and gel image analysis. Each step requires expensive equipment. Generally, a gel documentation system is widely used as a DNA detector. For the analysis of gel images, the most expensive imaging systems are used. Therefore, various studies are under way to create a gel documentation system of small size and low cost. In recent years, the rapidly developing open platform has been applied to various embedded systems. The open platform provides connectivity from a local area network to a global area network, making it easy to build various systems embedded into an Internet-of-Things (IoT) system. In other words, using the open platform makes it easier to develop an embedded system that can be accessed anytime and anywhere. In this paper, we propose a gel documentation system and compare its performance with that of the existing system, because the high-quality smartphone camera is being continuously developed for the open platform. Experimental results show that the proposed system has performance characteristics similar to those of the existing system while showing superiority in terms of price, size, and user convenience.

1. Introduction

The application of DNA detection has been expanding in many fields such as human and animal clinical diagnoses, pathogen detection, environmental testing, and forensic examination. Generally, to detect DNA, the following four steps should be performed: DNA extraction, DNA amplification, electrophoresis, and gel image analysis.[1–3] Also, expensive equipment is needed in each step.[4–6] The current gel documentation system (simply called Gel Doc) is a very expensive piece of equipment, mainly because of its camera and UV lamps.[7,8] Therefore, various researches are under way to develop a gel documentation system with low cost and small size.[9–12] In previous studies, attempts to reduce the size of UV lamps, the number of existing UV lamps, and the cost and size of the system were carried out.[13]

*Corresponding author: e-mail: cypark@hallym.ac.kr
https://doi.org/10.18494/SAM.2019.2099

ISSN 0914-4935
https://myukk.org/

In addition, we conducted research using an inexpensive compact digital camera instead of a digital single-lens reflex (DSLR) camera, which is an expensive imaging system used in conventional gel image analysis. Recently, the rapidly developing open platform has been applied to various embedded systems.[14–16] The open platform provides tools that enable users to use features, information, services, and more in any way they want. The open platform provides connectivity from a local area network to a global area network, making it easy to fabricate various systems embedded in an Internet-of-Things (IoT) system. Therefore, it is also easy to develop a system that can be accessed anytime and anywhere by using the open platform.

In addition, high-quality smartphone cameras are being developed on an open platform basis. In this paper, we propose a Gel Doc using an open-platform-based smartphone camera. Instead of the commonly used expensive DSLR cameras, we used a Raspberry Pi camera capable of IoT technology and conducted a performance test in a dark room.

Experimental results show that similar performance characteristics to the existing Gel Doc can be achieved using an open-platform-based smartphone camera. Therefore, by using diverse and easily accessible open-platform-based smart phone cameras, it has become possible to implement a small and inexpensive Gel Doc.

2. Materials and Methods

Figure 1 shows a block diagram of a Gel Doc. This Gel Doc consists of a camera box, a dark room, and a UV illuminator. The camera unit of the Gel Doc used in this study is a device for photographing agarose gel. We adopted a commonly used DSLR camera (Canon EOS 450D) and the Raspberry Pi camera module V2 proposed in this paper. Figure 2 shows the interior of a real Gel Doc. The Raspberry Pi camera module is designed to be removed during DSLR shooting.

Given that the Gel Doc is a device that captures the UV-induced illumination of the fluorescent material within the gel, the dark box was constructed to restrict light and ensure

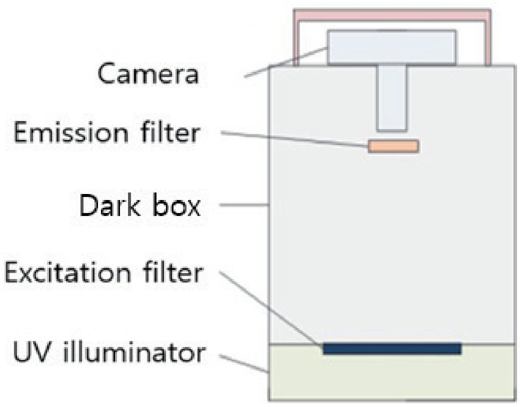

Fig. 1. (Color online) Block diagram of Gel Doc.

Fig. 2. (Color online) Interior of Gel Doc.

the appropriate documentation of fluorescent DNA bands. In general, the UV illuminator consists of four small photo UV lamps and two ballasts. Table 1 shows the specifications of the Raspberry Pi camera module v2.

The image shooting programs to control Canon EOS 450D and Raspberry pi camera take images of the gel and control the image of the gel from the computer. In addition, the images of gel can be previewed on the screen in real time, then the image can be conveniently captured. Figures 3 and 4 show the actual execution screens of the Raspberry Pi camera control program and DSLR remote programs.

For comparative experiments, DNA was sufficiently amplified to carry out polymerase chain reaction (PCR). To compare the performance characteristics of all cameras, 1, 1/2, 1/5, 1/10, and 1/20 dilutions of 1 ng/μL amplified *Chlamydia trachomatis* (CT) were used. The diluted DNA was mixed with agarose gel, which reacts with ultraviolet light. The agarose gel with the amplified DNA was electrophoresed for 25 min. To confirm the agarose gel after electrophoresis, we used a DSLR camera and a Raspberry Pi camera proposed in this paper.

Table 1
(Color online) Specifications of the Raspberry Pi camera.

Figure	Description
	Product name: Camera Module V2 Manufacturer: Raspberry Pi Video mode: 1080p30, 720p60, and 640×480P60/90

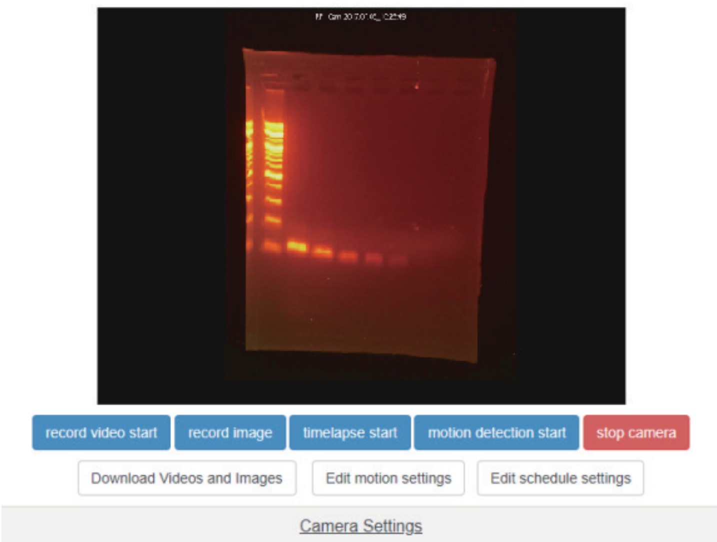

Fig. 3. (Color online) Raspberry Pi camera control program.

Fig. 4. (Color online) DSLR camera control program.

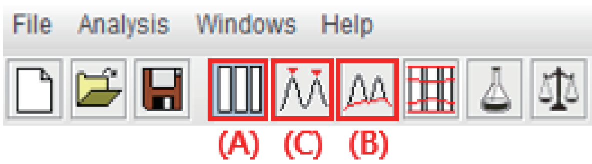

Fig. 5. (Color online) Main run buttons of GelAnalyzer2010a.

Figure 5 shows the main run buttons of GelAnalyzer2010a. The order is (A) → (B) → (C). (A) serves to locate DNA lines in the lane mode. (B) removes the background in the background subtract mode and shows the bright part of the band as a graph. (C) finds the highest part of the graph in the profile, and the brightness of the band can be confirmed on the basis of the row volume shown in the lower left corner.

3. Results

The Raspberry Pi camera and Canon EOS 450D were used to compare the open platform camera proposed in this paper and the conventionally used DSLR camera. Furthermore, the experiment was conducted with the shutter speed of the two cameras set to 1 s. For accurate comparative analysis, two images were cropped to a suitable size and then converted to a gray scale to reduce the noise in the image and obtain more accurate results. Figure 6 shows that the band part of the amplified DNA was separated by concentration using the GelAnalyzer after the gray scale conversion. Figure 6(a) shows an image taken with Canon EOS 450D, and Fig. 6(b) shows an image taken with the Raspberry Pi camera.

With qualitative analysis, it is difficult to accurately compare images. Therefore, we compared the brightness of the bands classified by concentration in numerical values to enable

(a) (b)

Fig. 6. (Color online) Images taken with (a) Canon EOS 450D and (b) Raspberry Pi camera.

Table 2
Row volumes of DNA bands classified by concentration.

Concentration of reagent	Canon EOS 450D	Raspberry Pi camera
1	1948	1237
1/2	1760	1240
1/5	1106	820
1/10	623	500
1/20	295	418

quantitative analysis. Table 2 shows the DNA bands photographed using the camera as row volumes. The higher the brightness of the DNA band, the higher the volume. As shown in Table 2, the values of DNA obtained at high concentrations are high when using Canon EOS 450D, but those of DNA diluted to the lowest concentration are high when using the Raspberry Pi camera.

4. Conclusions

We compared the images taken with a DSLR camera used in a general Gel Doc with those taken with the open platform camera proposed in this paper, and confirmed that the two images are similar. The performance characteristics of the two systems are also similar. Therefore, the proposed system can be miniaturized and more easily available than a conventional Gel Doc system.

Acknowledgments

This research was supported by the Hallym University Research Fund 2017 (HRF-201712-008).

References

1 R. Kodzius, K. Xiao, J. Wu, X. Yi, X. Gong, I. G. Foulds, and W. Wen: Sens. Actuators, B **161** (2012) 349.
2 E. Salm, Y.-S. Liu, D. Marchwiany, D. Morisette, Y. He, A. K. Bhunia, and R. Bashir: Biomed. Microdevices **13** (2011) 973.
3 J. Wu, R. Kodzius, K. Xiao, J. Qin, and W. Wen: Biomed. Microdevices **14** (2012) 179.
4 I. Bajla, I. Holländer, S. Fluch, K. Burg, and M. Kollár: Comput. Methods Programs Biomed. **77** (2005) 209.
5 A. M. Machado, M. F. Campos, A. M. Siqueira, and O. S. De Carvalho: Proc. X Brazilian Symp. Computer Graphics and Image Proc. (1997) 140.
6 X. Ye, C. Y. Suen, M. Cheriet, and E. Wang: Vision Interface **99** (1999) 19.
7 D.-J. Lee, S.-Y. Kim, J.-D. Kim, Y.-S. Kim, H.-J. Song, and C.-Y. Park: Int. J. Bio-Sci. Bio-Technol. **5** (2013) 151.
8 J.-S. Hwang, J.-D. Kim, Y.-S. Kim, H.-J. Song, and C.-Y. Park: Sens. Mater. **30** (2018) 397.
9 T. Goldmann, A. Zyzik, S. Loeschke, W. Lindsay, and E. Vollmer: J. Biochem. Bioph. Methods **50** (2001) 91.
10 T. G. Porch and J. E. Erpelding: J. Biochem. Biophys. Methods **67** (2006) 1.
11 D.-J. Lee, J.-D. Kim, Y.-S. Kim, H.-J. Song, and C.-Y. Park: Biomed. Eng. Online **17** (2018) 150.
12 J.-S. Hwang, J.-D. Kim, Y.-S. Kim, H.-J. Song, and C.-Y. Park: Biomed. Eng. Online **17** (2018) 156.
13 D.-J. Lee, S.-Y. Kim, J.-D. Kim, Y.-S. Kim, H.-J. Song, and C.-Y. Park: Int. J. Control Autom. **7** (2014) 33.
14 S. B. Khot and M. Gaikwad: Computing Communication Control and Automation (ICCUBEA, 2016) 1.
15 G. Mashette, P. Borole, and S. Bhat: IEEE Int. Conf. Recent Trends in Electronics, Information & Communication Technology (RTEICT) (2016) 1407.
16 A. Lewis, M. Campbell, and P. Stavroulakis: Measurement **87** (2016) 228.