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Validation Method for Automated Pipetting Device Using Camera

Jun Yeon[1,2], Hye-Jeong Song[1,2], Chan-Young Park[1,2], Yu-Seop Kim[1,2], Ki-Bong Nahm[3], Jong-Dae Kim[1,2*]

[1] Dept. of Convergence Software, Hallym University, Korea
[2] Bio-IT Research Center, Hallym University, Korea
[3] Dept.of Electron Physics, Hallym University, Korea
{mauver, hjsong, cypark, yskim01, kbnahm, kimjd }@hallym.ac.kr

Abstract. This paper presents a validation method based on image processing technique for point-of-care-test (POCT) diagnostic devices with an automated pipetting function. Proposed method is useful for indicating the overall malfunction of the entire device or for warning that the user has forgotten to load the required tip. A horizontal projection analysis can be utilized for robust identification of the tip and the holder area, and a vertical projection analysis is carried out for each area to detect tip absence of the tip and the tip and holder positions. Experimental results show that the proposed image processing technique for device monitoring worked well and without failure.

Keywords: Automated Liquid Handler (ALH), Image Processing, Validation

1 Introduction

The liquid handling used in experiments related to life sciences requires accuracy or precision but is a very tedious task requiring a considerable amount of time if carried out manually, requiring automation [1]. Most of the Automated Liquid Handler (ALH) systems are optimized for fast inspection of multiple samples at a large hospital. To apply the small hospital, a portable clinical test system using robotic automation has been recently developed.

In this paper, an image-based validation method is introduced for point-of-care test (POCT) diagnostic devices with automated pipetting. The proposed method is applicable to systems that have a holder for mounting a tip. Further, we need to notify the user of a device malfunction or a tip installation mistake by processing these validations in the device itself. Recently, because high-performance cameras for smartphones have become inexpensive, if an image processing approach method using such a camera is used, the validation can be conducted with a relatively simple and inexpensive method as compared to the conventional method.

Since the camera position and lighting are fixed in a device and the lighting condition can be known in advance, a simple image processing such as a fixed threshold and the projection analysis might be enough for the validation. In this study, we investigated whether a device can operate without error by applying a simple

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image processing technology for the test image set taken by emulating the position of the tip and the holder.

2 Materials and Methods

Figure 1 shows the overall flow of the algorithm for obtaining the positions of the tip and the holder. In an image acquired from the camera, since the x-axis position of the tip holder is always constant, the region of interest (ROI) is set in such a way that the tip and holder can be always seen on the basis of this position. The binary image is vertically separated into the tip part and the holder part. For the tip part, the position is obtained by using a vertical projection, and the holder position is obtained by using a horizontal projection.

The simplest method for obtaining the tip position is the selection of the center of function support where the profile function has a non-zero value. When there are many noises, this is not a stable method; however, this method can be applied when the imaging condition is good. Similarly, for the holder's top position, a zero to non-zero transition position of the projection function is selected.

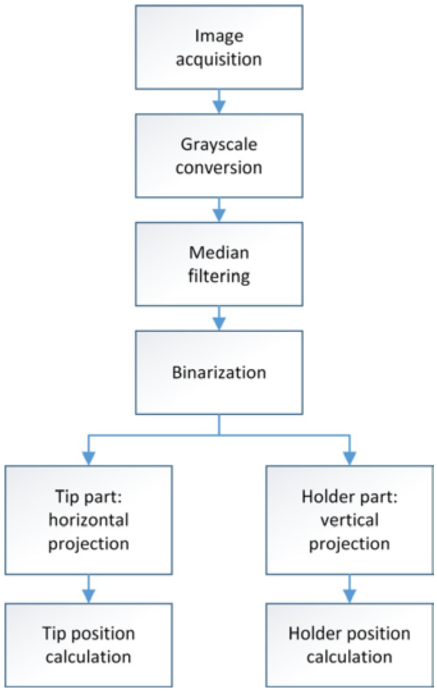

Fig. 1 Algorithm Flow.

The data preparations were prepared for the two conditions. First, to find out how precise the algorithm is for finding the tip and holder positions, imaging was performed for various tip and holder positions by moving the pertinent stepper motors. The tip center or the holder's top position was obtained for the acquired images and compared with the position of the stepper motor. The degree of precision was calculating by using a linear relationship between the stepper motor step and the image pixels because the stepper motor position is very precise.

Next, to accurately determine the absence of the tip, 75 images were acquired when the tip was present and when it was absent. The images taken in the tip presence images were acquired by having a variation of about 8 pixels on the basis of the tip center's correct position. On the other hand, by always positioning the holder's top position at the correct position, 25 holder images were acquired each when the holder was present, and when it was absent.

3 Results

The relationship of the tip stepper motor position and the tip pixel position obtained by image processing. As shown in Table 1, the slope is 0.46, implying a relation of about 2 motor steps per image pixel. The standard deviation of the error in pixel position is 0.79 pixel, which is less than 1 pixel position.

Also, the relationship of the holder between these two positions implies that there are about 5 motor steps per pixel position, and the standard deviation of the error in pixel position is 0.1 pixel.

The position of the tip or the holder as obtained by the proposed image processing method is very linear to the pertinent stepper motor's position (the coefficients of determination are 0.997 and 0.999 for the tip and the holder, respectively).

The results of the experiments conducted in the presence and the absence of the tip are summarized in Table 2. As shown in the table, the minimum support length when the tip was present is 54 and the maximum support length in this case is 56. In the case of the absence of the tip, the values were all 0. Therefore, whether the tip was present or not in the ROI could be accurately determined on the basis of support length. The results of the experiments conducted in the absence of the holder are summarized in Table 3, and whether the holder was present or not could be accurately determined on the basis of the start position.

From the above results, we concluded that the position information of the tip or the holder could be determined precisely by using simple image processing. This was possible because the imaging condition was highly controllable. The proposed image processing technique exhibited good performance with respect to estimating the tip and holder positions or determining the absence of these components.

Table 1. Precision of tip and holder positions obtained by image processing.

	Slope	Standard deviation of the error	R^2
Tip	0.461	0.79	0.993
Holder	0.191	0.10	0.999

Table 2. Experimental results obtained in absence and presence of tip.

Support length	Images acquired in absence of tip	Images acquired in presence of tip
Minimum	0	54
Maximum	0	59

Table 3. Experimental results obtained in absence and presence of holder.

Start position	Images acquired in absence of holder	Images acquired in presence of holder
Minimum	0	435
Maximum	0	436

4 Conclusion

In this study, an image-based validation method was introduced for diagnostic devices with automated pipetting, and its performance was verified. By verifying the linear correlation between image pixels for the motor position, we confirmed that the absence and the alignment of the tip and the holder were checked during the diagnosis by using an image processing technique on the images acquired by the device camera. The proposed simple image processing method using a camera sensor exhibited sufficient performance at a low cost for solving the validation problems that can occur in other POCT devices as well. Recently, because of the widespread use of many high-performance camera sensors, this method can be applied to other similar devices. By applying the proposed simple image processing method to a device with a highly controllable imaging condition, user mistakes and/or device malfunction can be prevented by detecting a device failure. Furthermore, if an algorithm for liquid volume is additionally developed, it will be possible to perform liquid volume verification.

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References

1. F. Kong, L. Yuan, Y. F. Zheng and W. Chen "Automatic liquid handling for life science: a critical review of the current state of the art", J Lab Autom, 2012, Vol. 17, No. 3, pp. 169-185.
2. W. S. You, J. J. Park, S. M. Jin, S. M. Ryew, and H. R. Choi "Point-of-care test equipment for Flexible laboratory automation", J Lab Autom, 2014, Vol. 19, No. 4, pp. 403-412.
3. B. Srinivasan, and S. Tung "Development and applications of portable biosensors", J Lab Autom, 2015, pp. 1-25.