Liquid Level Detection of Syringe Pump and Syringe Based on Machine Vision

Yunxi Liu\textsuperscript{a}, Miao Guo\textsuperscript{*} and Jingmin Gao\textsuperscript{b}, Yue Li\textsuperscript{c}

School of Automation, Beijing Information Science and Technology University, Haidian District, Beijing, China
\textsuperscript{a}email: 791882369@qq.com
\textsuperscript{b}email: gaojm_bitii@163.com
\textsuperscript{c}email: liyue030617@163.com
\textsuperscript{*}Corresponding author’s e-mail: 20192379@bistu.edu.cn

Abstract. When a nurse uses a syringe pump to infuse the patient, the nurse needs to contact the patient several times at a close range. This article proposes a method to detect the infusion of the syringe pump to reduce the frequency of contact between the nurse and the patient and reduce the labour intensity of the nurse. Using machine vision technology, filter and Prewitt operator are combined to process the acquired syringe pump pictures to obtain the accurate liquid level position. The image is captured by an industrial camera. After grayscale processing and image filtering, the Prewitt edge detection algorithm is used to obtain a clear edge image, and then the corner detection algorithm and pixel coordinate display are used to detect the liquid level of the syringe without external auxiliary measuring equipment. After performing multiple tests on 26 different liquid level images of a 50ml syringe, the results show that proposed method is effective to measure the liquid level in a non-contact way. The test result shows that the relative error is When the scale is 2ml to 16ml, the relative error range is -66% to -0.63%. When the scale is 18ml to 50ml, the relative error range is -1.86% to -1.19%. Among the 26 pictures, the absolute error of 22 pictures is within ±1ml, and the absolute error of 19 pictures is within ±0.5ml.

1. Introduction

Liquid level detection technology plays an important role in biomedicine, food and beverage, daily chemical products and petroleum exploration. In order to ensure product quality and production safety, the era of direct manual monitoring and intervention in the production process no longer exists. Traditional liquid level measurement technology can no longer meet the requirements of rapid detection.

At present, the liquid level detection methods mainly include direct measurement and indirect measurement. Due to the complexity of the measurement environment, indirect measurement methods are mostly used in industrial practice. The liquid level signal is converted into other related signals for measurement, such as pressure signal, electrical signal and image signal. Applying the imaging method to the liquid level detection of syringe pumps and syringes can achieve better real-time performance and higher accuracy, which can save operating time of experimental personnel and reduce artificial errors.

This paper proposes a method that combines filtering, edge detection and corner detection to detect the liquid level of the syringe. First the Rect function is used to extract the area to be detected. Grayscale processing and bilateral filtering are applied to remove the background noise. Then Prewitt operator is
used for edge detection. Finally, Harris corner detection algorithm is used to get the coordinates and calculate the liquid level.

2. System description

Figure 1 shows the experimental equipment: FC113 injection pump from LIFEPUM MEDITECH CO., LTD., 50ml medical syringe, 250ml beaker, an infusion tube, a camera stand to fix the camera on the syringe pump and a laptop. The camera pixel is set to 640*480 pixels.

3. Results and Discussions

3.1. Selection of ROI area

The syringe pump device[1] needs to fix the syringe during the experiment. This obscures a part of the experiment target, which brings difficulties to the identification process. Since the position of the black rubber in the syringe is the position of the liquid level, only the red frame area in Figure 2 and 3 is selected.

During the experiments, the position and angle of the camera are fixed. The Rect function[2] is used to construct a rectangular area to obtain the liquid level information of the syringe bolus, eliminate other unnecessary factors, reduce processing time, and improve subsequent working effect.
3.2. Grayscale processing of RGB images
The pictures of the syringe bolus collected by the camera are colour pictures and contain a lot of unnecessary information. In this experiment, the gray image can fully express the characteristics required by the experiment. So first of all, the RGB image needs to be grayed out[3]. As shown in Figure 4. The weighted average method used is:

\[ R = G = B = \frac{R + G + B}{3} \]  

(1)

Figure 4. Gray image acquired by the weighted average method

3.3. Image filtering
Image filtering can reduce image noise while maintaining image details and texture characteristics. It is an indispensable process in the preprocessing process. The further analysis and processing of subsequent images depend on the quality of the image filtering effect. Figures 5-9 show the filtering results of five commonly used filters.

By comparing above five filters, the bilateral filter can effectively obtain the contour of the black rubber in the syringe. Considering the subsequent accuracy, this article selects the bilateral filter as the filtering algorithm.

4. Edge detection
The current edge detection algorithms are mainly based on the first and second derivatives of image intensity. The main methods include Canny operator[4], Laplacian operator[5], Prewitt operator[6], Roberts operator[7], etc.

4.1. Comparison of the effect of edge detection methods
In this experiment, five commonly used edge detection algorithms are compared, as shown in Figure 10-14. Since the meaning of edge detection in this experiment is to prepare for the subsequent corner detection, the L corner point of the black rubber must be highlighted. Under this premise, it is clear that the Prewitt edge detection algorithm has the best effect on the image, and the edges are sharpened. The effect conclusions and running time of the five edge detection algorithms are shown in Table 1.
Figure 10. Canny algorithm

Figure 11. Prewitt algorithm

Figure 12. Roberts algorithm

Figure 13. LoG (Laplacian of Gaussian) algorithm

Figure 14. DoG (Difference of Gaussian) algorithm

Table 1. Comparison of the effect of edge detection methods.

| Rubber contour highlighting effect | Running time/s |
|-----------------------------------|----------------|
| Canny algorithm                   | General 0.402  |
| Prewitt algorithm                 | Good 0.366     |
| Roberts algorithm                 | Not Good 0.324 |
| LoG algorithm                     | Not Good 0.291 |
| DoG algorithm                     | General 0.353  |

5. Liquid level detection

5.1. Corner detection algorithm
The Harris corner detection method is based on the autocorrelation function of the local signal. The local autocorrelation function has the function of detecting small changes caused by the displacement of the signal in various directions[8]. Principle diagram of Harris corner detection is shown in Figure 15.

Figure 15. Principle diagram of Harris corner detection

5.2. Detection steps
Step 1: Calibration: The above-mentioned corner detection algorithm detects the pixel abscissa $x_0$ and $x_{50}$, and pixel distance $d$ when the syringe is at 0ml scale and 50ml scale.

\[ d = x_{50} - x_0 \] (2)
Step 2: Calculation: Set the abscissa of the detected point pixel as $x$, the true distance detected is $D$.

\[
\frac{x - x_0}{d} = \frac{D}{50}
\]  

(3)

Through the experiment, only the syringe injection moves and other environments remain unchanged: Two corner coordinates are detected, and the smaller corner coordinates are selected. 50 ml scale pixel abscissa is 248 pixels, as shown in the Figure 16:

Figure 16. 50 ml calibration of corner detection

Two corner coordinates are detected, and the smaller corner coordinates are selected. 0 ml scale pixel abscissa is 28 pixels, as shown in the Figure 17:

Figure 17. 0 ml calibration of corner detection

It can be obtained by formula (2): $d = 220$ pixels, $x_0 = 28$ pixels.

The syringe is 50 ml, and there are 26 scale lines in all. The experiments in this article correspond to the detection of 26 syringe pictures corresponding to different scales, of which 22 pictures are within $\pm 1.00$ ml, 19 pictures are within $\pm 0.50$ ml, and the maximum error of the test results is 1.95 ml. Among the 26 detected pictures, 24 pictures have a relative error of -31.75% to 1.2%, 21 pictures have a relative error of -10% to 1.2%, and 16 pictures have a relative error of -1% to 1%.

Figure 18. Comparison between measured scale and reference scale
6. Conclusions
In this research, a detection method combining filtering, edge detection, corner detection and pixel coordinate display is proposed to detect the remaining volume of the syringe in the syringe pump during the injection process. The test result shows that when the scale is 2ml to 16ml, the relative error range is -66% to -0.63%. When the scale is 18ml to 50ml, the relative error range is -1.86% to -1.19%. Among the 26 pictures, the absolute error of 22 pictures is within ±1ml, and the absolute error of 19 pictures is within ±0.5ml.

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References
[1] M. R. Islam, R. Zahid Rusho and S. M. R. Islam, "Design and Implementation of Low Cost Smart Syringe Pump for Telemedicine and Healthcare," 2019 International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST), 2019, pp. 440-444, doi: 10.1109/ICREST.2019.8644373.
[2] H. B. Kekre, T. Sarode and R. Vig, "An effectual method for extraction of ROI of palmprints," 2012 International Conference on Communication, Information & Computing Technology (ICCICT), 2012, pp. 1-5, doi: 10.1109/ICCICT.2012.6398207.
[3] I. Ahmad, I. Moon and S. J. Shin, "Color-to-grayscale algorithms effect on edge detection — A comparative study," 2018 International Conference on Electronics, Information, and Communication (ICEIC), 2018, pp. 1-4, doi: 10.23919/ELINFOCOM.2018.8330719.
[4] L. Yuan and X. Xu, "Adaptive Image Edge Detection Algorithm Based on Canny Operator," 2015 4th International Conference on Advanced Information Technology and Sensor Application (AITS), 2015, pp. 28-31, doi: 10.1109/AITS.2015.14.
[5] Li Junfeng, Y. Aiping, D. Wenzhan and P. Haipeng, "On Image Edge Detection Based on Grey Absolute Degree of Incidence and LOG Operator," 2007 Chinese Control Conference, 2007, pp. 480-484, doi: 10.1109/CHICC.2006.4346839.
[6] L. Yang, X. Wu, D. Zhao, H. Li and J. Zhai, "An improved Prewitt algorithm for edge detection based on noised image," 2011 4th International Congress on Image and Signal Processing, 2011, pp. 1197-1200, doi: 10.1109/CISP.2011.6100495.

[7] G. N. Chaple, R. D. Daruwala and M. S. Gofane, "Comparisions of Robert, Prewitt, Sobel operator based edge detection methods for real time uses on FPGA," 2015 International Conference on Technologies for Sustainable Development (ICTSD), 2015, pp. 1-4, doi: 10.1109/ICTSD.2015.7095920.

[8] S. Han, W. Yu, H. Yang and S. Wan, "An Improved Corner Detection Algorithm Based on Harris," 2018 Chinese Automation Congress (CAC), 2018, pp. 1575-1580, doi: 10.1109/CAC.2018.8623814.