Study on monitoring infusion rate based on computer vision

Qingchen Yu *

Beijing University of Posts and Telecommunications Beijing, China

* Corresponding Author Email: 2020213106@bupt.cn

Abstract. A computer vision based infusion monitoring method and system is proposed to solve a series of technical problems such as inconvenient use of the existing infusion monitoring system. The technical scheme includes video capture module, voice alarm module and main control module. The video capture module is used to collect the real-time image information of the drip pot part of the infusion equipment and transmit the collected image information to the main control module. The main control module processes the image information transmitted by the video capture module, uses the computer vision principle and self-designed algorithm to judge the real-time flow rate of the infusion equipment, judges whether the infusion is completed according to the preset conditions, and timely controls the voice alarm to give an alarm. The system uses computer vision technology to accurately judge whether the infusion equipment has completed infusion and give an alarm. It is simple to use, does not hinder traditional manual monitoring, and provides convenience for unattended patients, patient families, and nurses.

Keywords: *Monitoring the infusion rate; Computer vision; OpenCV*.

1. Introduction

Intravenous infusion technology is a commonly used clinical medical means, which requires family members, patients and medical staff to monitor at any time. Especially because of the epidemic situation, family members cannot accompany in the hospital. The infusion process can only be monitored by the patient himself. After the infusion, the nurse is notified to change the medicine. The infusion takes a long time, and the patient cannot rest at ease during the whole process. If the machine is used to replace the human eyes and keep staring at the infusion dripping bottle, the patient or his family members will be alerted when the liquid in the dripping bottle is detected to be almost finished, so that the patient can rest at ease. The current computer vision technology is the technology that computer simulates human visual process. It can feel the environment and has the human visual ability. If this technology is applied to infusion monitoring, a completely computer vision based infusion monitoring system can be provided, which can not only solve the problems of patients, but also overcome some shortcomings of existing infusion systems.

2. Current status of real-time monitoring of infusion

At present, there are many similar automatic infusion monitoring devices, which mostly rely on high-precision tension sensor or infrared photoelectric type to measure the quality of the remaining liquid medicine in the infusion bottle. The sensor needs to be placed on the infusion device, which has a certain impact on the original equipment. In addition, the actual application is complex and changeable, and these devices have some shortcomings, such as inconsistent quality of infusion bottles, inflexible installation troubles, and sensitive to light changes, so that they have not been widely used. [1][2][3][4].

There is also an intelligent infusion monitoring system for medical infusion monitoring. The system includes main control module, WIFI module, voice alarm and server, as well as high-precision pull sensor and high-precision micro camera. The system mainly relies on high-precision tension sensor to measure the residual liquid quality of infusion bottle, and high-precision micro camera is used to collect the image information of infusion bottle. The system is relatively complex, which needs to be connected to the medical care system, and mainly relies on the tension sensor to measure the remaining

infusion fluid. The sensor needs to be placed on the infusion equipment, which has a certain impact on the original equipment. [5]

There are also infusion detection systems based on video image processing, such as real-time detection system of infusion drip speed based on video image. Its main principle is to use the camera to obtain the video image of the infusion bucket position, use the embedded system to process the above image in real time, obtain the infusion drop speed information, and display it in real time on the monitoring terminal. The advantage of this method is that it adopts a non intrusive scheme, which can be monitored 24 hours, has no special requirements for the infusion device, does not hinder the traditional manual monitoring, and is convenient and flexible to install. The disadvantage is that due to the limitation of the processing speed of the hardware platform, the infusion speed measured by the system has some errors and the accuracy is not high. The impact of personnel walking and collision on the device in the actual application environment is not considered, so the practicability is not high. [6]

All the above detection methods can complete infusion detection, but there are still many shortcomings. So far, at present, the infusion in the hospital basically does not apply automatic infusion monitoring, but the patient or family members monitor themselves at any time, and notify the nurse when the infusion is almost finished. Especially in the current epidemic stage, the patient has no family members to accompany him, and even if he has hired a nurse, he cannot always stay with the patient. This also shows that the existing automatic infusion monitoring is not applicable and can not be popularized. If these problems can be solved, the system will have a large number of potential consumers, broad market prospects, and great development potential and application market in the future.

Therefore, the main purpose of this design is to detect the infusion more intuitively, conveniently and accurately. This paper presents a method and system of transfusion monitoring based on computer vision. Make full use of computer vision algorithm and technology to collect real-time image information of infusion equipment and judge whether infusion is completed. With this method and system, the family members or patients can be reminded from the alarm signal sent by the monitoring system when the infusion is completed, and the nurses can be notified to deal with it in a timely manner. On the one hand, the efficiency is improved, and family members or patients do not need to keep an eye on the infusion equipment; On the other hand, it can improve the safety and reduce the harm caused by human negligence; It also provides convenience for infusion nurses, and can greatly reduce the labor intensity of patients' families and medical staff.

3. Infusion real-time monitoring system

The monitoring system is mainly based on computer vision technology to automatically monitor and count the infusion speed of infusion equipment, and can timely notify patients or family members before the completion of infusion according to the speed. On the one hand, the efficiency is improved, and family members or patients do not need to keep an eye on the infusion equipment; On the other hand, it can improve the safety and reduce the harm caused by human negligence.

The system includes main control module, video capture module and alarm module. The main control module is connected with the video capture module and the alarm module respectively. The video capture module faces the direction of the infusion equipment, which is used to collect the real-time image information of the infusion equipment and transmit the collected image information to the main control module. The main control module processes the image information from the video capture module, monitors the real-time status of the infusion equipment, and triggers the alarm module to send out the alarm information if the infusion is judged to be completed. This system can effectively monitor the infusion scenes of different infusion equipment, so as to remind patients to change fluids in time. The specific process is shown in Fig 1:

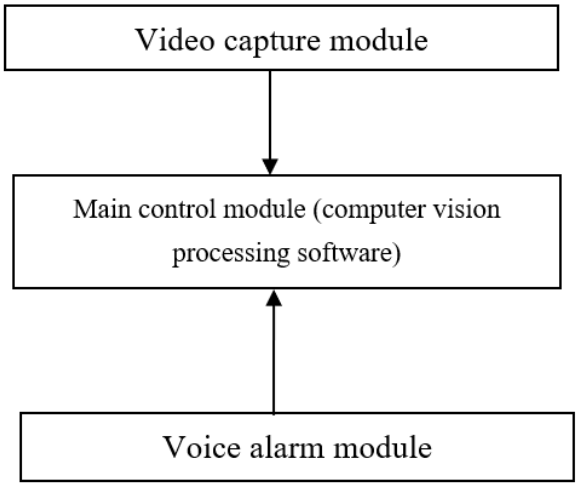


Fig 1. System Diagram.

In the system shown in the figure, the technical highlight lies in the innovation of the computer vision-based processing algorithm of the main control module. On the basis of using the traditional algorithm of OpenCV, an algorithm that can accurately identify the moving area of water droplets is designed to accurately count the droplet speed and timely send alarm information, improve the image processing speed and speed measurement accuracy, and improve the reliability of the software and make it practical in consideration of the actual application environment. Specifically, the video capture module captures the real-time image information of the infusion equipment, and transmits the collected real-time image information to the main control module; According to the real-time image information received, the main control module uses computer vision algorithm to monitor the real-time flow rate of the infusion equipment, and judges whether the infusion is completed according to the preset conditions. If the infusion is completed, it controls the voice alarm to alarm. If the infusion is not completed, it continues to monitor; The voice alarm module gives an alarm, and can also display the flow rate of infusion equipment in real time.

4. Video image acquisition

The video image acquisition module is mainly completed by the monitoring probe. The main body of the monitoring probe can be a WIFI camera, which can be fixed in a certain way to make it aim at the infusion equipment, or it can directly use the mobile phone camera function, and the fixed position can aim at the infusion equipment to collect images, as shown in Fig 2.



Fig 2. Video Image Acquisition.

The main control module continuously reads the video images sent by the monitoring probe, analyzes and processes them, obtains the real-time infusion speed information, and sends out the alarm

information of too fast infusion or infusion completion according to the preset threshold. At the same time, the real-time infusion speed can be displayed on the terminal through the network, which is convenient for patients to monitor the infusion status in real time.

5. Video image processing

After getting the drip video image from the video capture module, the main control module needs to analyze its motion image to obtain the infusion speed information. This system uses the algorithm based on computer vision OpenCV and the inter frame difference method to realize the motion analysis of the video image of infusion drops.

In order to avoid the impact of dropper shaking and improve robustness, it is not necessary to process the actual image, but only to intercept a certain size of local image for processing, which can also greatly improve the real-time image processing capability. First of all, we need to segment the dropper part that we are interested in for special processing, that is, to obtain image positioning, and then perform inter frame difference processing, and then calculate the drip rate, and determine whether infusion is completed according to the rate to send an alarm to the user. This part of the algorithm design is the main and key part of the system.

5.1 Computer vision

Computer Vision (CV) is a subject that uses computer algorithms to recognize images. Furthermore, it refers to the use of cameras and computers to replace human eyes to recognize, track and measure objects, and to further do graphics processing, so that computer processing can become an image more suitable for human eyes to observe or transmit to the instrument for detection. OpenCV is an open source computer vision framework, which simply provides you with a framework for processing images and videos. Compared with the deep learning model, OpenCV provides some traditional algorithms related to images. Because the infusion equipment to be monitored is transparent, it is found in the early research that the recognition of transparent objects using the depth learning model has some limitations that are not ideal, and requires a large number of learning processes, so the traditional image recognition algorithm is selected. We can use some basic algorithms of OpenCV, including image or video reading, writing and display, image enhancement and restoration and other basic algorithms to apply to our algorithm, read the video image, and identify the parts we are interested in for real-time monitoring of infusion drip rate, real-time processing, and obtaining infusion drip rate information.

5.2 Image positioning

Because of the transparency of the infusion equipment and the complexity of the background, we need to design an algorithm for the infusion drip rate counting based on the basic algorithm of OpenCV. First of all, the algorithm needs to be able to accurately identify the moving area of water droplets in the complex environment of practical application and change the whole image processing into a local image processing. It greatly reduces the burden of image processing, meet the real-time speed measurement requirements and accuracy of the system, and make it practical. Because the algorithm can automatically identify the moving area of water droplets, it only requires the camera to aim at the infusion equipment, without fixing the position of camera and the drip.

This algorithm uses some basic algorithms of OpenCV, as shown below: [7] Image or video reading: imread(), reading an image file, and the returned result is a matrix that stores image data. This function will automatically decode the image. Imwrite(), which writes the matrix storing image data as an image file. For example, jpg and png images. It will automatically encode the image. These two functions, together with imshow(), can read, write and display pictures. OpenCV can not only read and write pictures, but also videos. It can read each frame of the video as a matrix, or write a frame to the video file.

Image enhancement and restoration: The purpose of image enhancement and restoration is to improve the image quality, such as removing noise and improving the image definition. Image enhancement does not consider the reason of image degradation, and highlights the parts of interest in the image. If the high-frequency component of the image is enhanced, the contour of the object in the image is clear and the details are obvious; For example, enhancing the low-frequency component can reduce the impact of noise in the image. Image restoration requires a certain understanding of the causes of image degradation. Generally speaking, a "degradation model" should be established according to the degradation process, and then some filtering method should be used to restore or reconstruct the original image.

Image segmentation is one of the key technologies in digital image processing. Image segmentation is to extract meaningful features from an image, such as edges and regions. Image edge processing method: edge detection.

Because the shape and size of the water droplet movement area we need to locate are relatively fixed, we can use a standard dropping pot shape as the template. First, edge detection is performed on the acquired image, and then feature value matching is performed with the template, including image centroid, center of gravity, edge points and other feature points matching one by one. By adjusting the matching threshold through experiments, more accurate positioning has been achieved.

5.3 Inter frame difference method

The inter frame difference method [8][9][10] is a motion detection method based on pixel contrast, which mainly uses two or more frames of captured data for comparison, and captures the contour of target motion through comparison difference to complete target detection. The algorithm principle is shown in Fig 3.

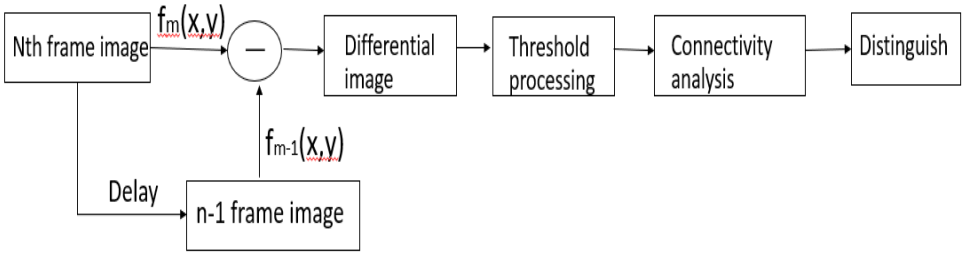


Figure 3. Principle of inter frame difference method.

In Fig 3, assuming that the grayscale data of the m-th frame image is fm (x, y), the m-1st frame is fm-1 (x, y), and (x, y) is discrete pixel coordinates, the differential grayscale image data Dm (x, y) between them is expressed as.

$$Dm(x,y) = |f_m(x,y) - f_{m-1}(x,y)| \tag{1}$$

Dm (x, y) reflects the changes of the previous and current frame images. After the inter frame difference processing of video images, it is usually necessary to filter the difference data to eliminate interference. The main methods are median filtering. Binarization means that after obtaining the difference image data, it is necessary to select an appropriate threshold R to determine the position where the previous and current frame images change. If the value of a pixel is greater than the threshold R, the pixel is defined as "1", which is the target area of the motion; On the contrary, it is defined as "0", which is the static background. Expressed as

$$R_m(x,y) = \begin{cases} 0 & Dm(x,y) \le R \\ 1 & Dm(x,y) > R \end{cases} \tag{2}$$

In the above formula, R is the threshold value of binarization. After binarization, connectivity analysis is carried out on the pixel point that is 1. When the connected area is greater than the given threshold, it is determined that a moving target is detected, and the area is marked as the area where the target is located.

5.4 Acquisition of infusion drip rate

Through image positioning, we can accurately locate the moving part of the water droplet, that is, the dropping pot. Then, the inter frame difference method is used to calculate the drip rate of positioning part. If the value exceeds a certain threshold, it is judged that a drip has occurred, and then the drip rate is calculated according to the interval between the two vibrations.

The key of binarization in inter frame difference method is to select appropriate threshold to segment moving objects and background. The common method is to select an approximate threshold value based on experience, and the threshold value is fixed during the detection process. In the actual detection, due to the influence of noise interference and illumination, even if the filtering process is carried out in advance, the detection results of this method will be greatly affected. Therefore, it is very important to update the threshold in time and get a reasonable dynamic threshold in practical application.

The threshold algorithm of cyclic iteration is to repeatedly update the histogram of the sub image to obtain the highest peak value, and repeatedly use cyclic iteration to calculate to finally obtain the threshold value. [9]. Because of continuous iteration, the more cycles, the easier it is to use the local features in the image. The specific methods are as follows:

1) Calculate the minimum and maximum grayscale values fmin0 and fmax0 in the image, assuming that the initial threshold is

$$T_k = \frac{f_{min\,0}+f_{max\,0}}{2} \tag{3}$$

2) The threshold value is used to segment the image, and the average gray value fA and fB of the background and moving target are calculated

$$f_A = \frac{\sum_{f(x,y)<T_k} f(x,y)N(x,y)}{\sum_{f(x,y)<T_k} N(x,y)} \tag{4}$$

$$f_B = \frac{\sum_{f(x,y)>T_k} f(x,y)N(x,y)}{\sum_{f(x,y)>T_k} N(x,y)} \tag{5}$$

In the above formula, f (x, y) represents the gray value at image (x, y), and N (x, y) represents the weighted value at image (x, y). Generally, N (x, y)=1 is taken by default.

3) Re average the new threshold

$$T_{k+1} = \frac{f_A+f_B}{2} \tag{6}$$

4) If the calculated new threshold Tk+1=Tk, the cycle is ended; otherwise, k=k+1, continue to step 2) until the conditions are met.

6. System workflow

The system includes main control module, video capture module and alarm module. The main control module processes the real-time information from the video capture module, monitors the real-time status of the infusion equipment, and needs to analyze its motion image to obtain the infusion speed information. By contrast, the frame difference method is used to realize the motion analysis of the video images of infusion drops. If it is judged that the infusion is completed, the alarm module will be triggered to send out alarm information. The video capture module can collect the real-time information of the infusion equipment, and transmit the collected real-time information to the main control module. The acquisition module can be an external camera, fixed on the infusion equipment, or placed in other positions, aiming at the drip position for video capture. The alarm module can flexibly and accurately remind patients to change dressing.

In the system workflow, first open and configure the WIFI camera; Then the video image is read and processed, and the algorithm can automatically determine the location area of the dripping pot image where the water drops are located; Then, a video image is read at a fixed time and the grayscale

information is obtained. The image data can be read and processed at a fixed time of 8 frames per second. The pre and post difference processing, filtering and binarization processing are performed on each frame image acquired at a fixed time to count the number of pixels before and after the image changes. Determine whether a liquid level vibration has occurred according to the number of changed pixels; If there is no liquid level vibration, start to read and process the image again; If it is determined that liquid level vibration has occurred, calculate the time interval according to the frame number of this vibration and the frame number of the last vibration to obtain the current real-time droplet velocity and display it on the monitoring terminal. Then judge whether the infusion speed exceeds the preset speed range. If it is too fast or too slow, an alarm will be given. If not, continue to read the video image.

Generally, the infusion speed of adults is 40-60 drops/min, while that of children and the elderly is 20-40 drops/min. The infusion speed of patients with cardiopulmonary function is slower, and the infusion speed is related to the type of drug solution. Therefore, the monitoring system needs to set the minimum and maximum infusion speed at first when it is working. When the speed is lower than the minimum speed, it is considered that the infusion is abnormal or the infusion is about to end. When the speed is higher than the maximum speed, it will give a prompt of too fast alarm. Default values can be set in advance, for example, for normal people, the minimum value is 15 drops/min, and the maximum value is 120 drops/min. If the actual situation is different, reset it. When it is lower than the minimum value or higher than the maximum value for 5 seconds, the alarm information will flash on the terminal screen, and the buzzer and LED will start flashing alarm at the same time.

7. Conclusion

Hang the infusion bottle and place the camera at the place facing the infusion equipment. Adjust the liquid level height and dropping speed in the dropping pot. From the instantaneous detection results obtained on the monitor of the main control module, it can be found that the processing speed is 8 frames/second, and the dropping speed hovers between 80-120 drops/minute. At this time, the maximum limit is 120 drops/minute. Since the maximum speed is not exceeded for 5 seconds, the display is normal. The actual measurement results at the processing speed of 8 frames/second show that the speed can be measured instantaneously. When the infusion speed is too fast or too slow, the alarm sent out is very timely and effective. It shows that the system can meet the needs of ordinary infusion monitoring. The image processing speed can be configured. With the improvement of the image processing speed, the timing interval of image processing is shortened, and the speed measurement accuracy is higher.

To sum up, this paper proposes a real-time monitoring system of infusion velocity based on video images, which can display infusion velocity in real time and send out alarm of abnormal velocity in time. The next step is to improve the speed measurement accuracy and software reliability, and at the same time, consider the impact of personnel walking and collision on the device in the actual application environment, so as to improve the robustness of the software and make it practical.

Reference

[1] Yu Xiangying, Sun Xiaohong, Wang Yongzhen, Development and application of new spring infusion alarm [J] Nursing Research, 2003,17 (9): 1010

[2] Jiang Yong. Research on infusion monitoring system based on photoelectric sensors[J]. Medical Equipments, 2010, 23(12): 9-11.

[3] Bao Jinming, Rui Chengsheng. Medical infusion liquid drop speed monitoring method and device[P]. Chinese Patent: 101856525B, 2010-06-07.

[4] W-1-2000 medical infusion bottle (alarm) monitor [EB/OL]. [2001-01-24] www.pharmnet.com.cn/product/detail/202472.html.

[5] Zhang Haibin; Dong Dan; Zhao Huanlei, Chinese patent CN110101940A 2019-05-16 for transfusion monitoring system based on computer vision

[6] Huang Yue et al., Real time detection system of infusion drip speed based on video image, 2013:05-0685-06

[7] Learn OpenCV4 Python based algorithm and practice Xiao Ling, Electronic Industry Press

[8] Murat TekalpA. Digital video processing[M]. Beijing: Tsinghua University Press, 1998:158-160.

[9] Lipton Alan J, Hironobu Fujiyoshi, Patil Raju S. Moving target classification and tracking from realtime video[C]//Proceedings of Fourth IEEE Workshop on Applications of Computer Vision. Princeton, NJ: IEEE,1998:8-14.

[10] Yang Qinghua, Li Wei, Shu Lanying, et al. Skin extraction based on double Gaussian and inter-frame difference[J]. Journal of Data Acquisition and Processing, 2013, 28(1):92-97.