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Vein Detection and Cannula Insertion using Raspberry Pi

Muhammad Naisal Ansar
Department of Electronics and Communication
Sahrdaya College of Engineering and Technology
Kodakara, India
muhammad119007@sahrdaya.ac.in

Aljo Jose
Department of Electronics and Communication
Sahrdaya College of Engineering and Technology
Kodakara, India
aljo@sahrdaya.ac.in

Angela Sabu
Department of Electronics and Communication
Sahrdaya College of Engineering and Technology
Kodakara, India
angela119700@sahrdaya.ac.in

Jisa Joy
Department of Electronics and Communication
Sahrdaya College of Engineering and Technology
Kodakara, India
jisa119702@sahrdaya.ac.in

Lijo Poulose
Department of Electronics and Communication
Sahrdaya College of Engineering and Technology
Kodakara, India
lijo119003@sahrdaya.ac.in

Ambily Francis
Department of Electronics and Communication
Sahrdaya College of Engineering and Technology
Kodakara, India
ambilyfrancis@sahrdaya.ac.in

Abstract—There have been cases where it is difficult to recognise veins due to a lack of skilled medical personnel in a number of nations, including underdeveloped nations.Here, a method for automatic injection with vein detection is suggested as a solution for this issue. The device is capable of detecting veins automatically and injecting cannulas into them. Finding the best vein for this process can be challenging, even for experienced doctors, which is a significant issue for the medical industry. When veins are not detected correctly, they can lead to severe complications, including blood clots, rashes, bruises, and even amputation.During the vein detection process, an altered near IR camera is used to take pictures of the veins, from which, through image processing, by applying grey scaling, CLAHE, bilateral filter the vein is identified. The position for injecting can be determined by using bounding box.The centroid of the bounding box determines the position of the vein. The determined vein is considered as the injecting point. Using the IR camera and LIDAR sensor the 3 coordinates of the point is measured and the corresponding data is given to the robotic arm where the cannula is present. After the data is received, with the help of robotic arm the cannula is precisely inserted to the point on the vein. Live video feedback is offered to guarantee the needle's exact alignment and the identified vein spot. To put up all the required components, a mechanical structure is created. The medical industry's modernization could significantly benefit from this initiative.

Index Terms—Image Processing, Vein segmentation, Feature extraction, Robotics

I. INTRODUCTION

Finding the location of veins is crucial in the medical field so that the doctor or nurse can assist the patient. It can be difficult for them to locate veins and insert needles in patients' arms at the beginning of their experiments. During the second experiment, it will cause discomfort to the patient. Sometimes, even highly trained nurses and doctors have difficulty finding the blood veins on the first attempt.Patients may suffer adverse outcomes if a cannulation fails. Inappropriate intravenous in-jection administration can lead to a number of issues, including skin swelling, rashes, nerve damage, blood clots, allergies, the development of dark patches in the veins, and arterial damage that can cause haemorrhage or gangrene.

An accurate vein location device is essential in such cases. Automatic vein detection refers to the process of using tech-nology to locate veins in the body without the need for manual identification. This technology can be useful in a number of medical procedures, including blood tests, IV insertions, and cosmetic procedures. Vein detection technology typically involves the use of infrared light to highlight the veins beneath the skin, which can then be projected onto a monitor for visualization by the healthcare professional.Each of these techniques has its own advantages and limitations, and the choice of technique will depend on the specific application and the preferences of the medical professional. Overall, automatic vein detection can help improve the accuracy and efficiency of medical procedures, while also reducing discomfort for the patient.

An automatic cannula injector is a device that is used to automatically insert a cannula into a patient's body for the purpose of delivering fluids or medications. A cannula is a small tube that is inserted into a vein, artery, or body cavity to allow for the administration of fluids, medication, or to withdraw blood for testing. Cannula insertion technology uses a variety of techniques, including ultrasound guidance and robotic-assisted procedures, to accurately insert the cannula into the vein. When treating elderly, dark-skinned, or adult patients, some drug delivery doctors have difficulty accessing veins.Additionally, when getting blood transfusions or drawing blood, it's important to know where the veins are. Although there has been a lot of research in this area and many devices have been created, the main challenges are their expense and portability. Information regarding the diameter and the depth of the veins may be obtained using the ultrasound technique.

Previous studies have demonstrated that the use of an ultrasound device increased the rate of successful catheter placement at the first attempt, particularly in difficult venous access. Additionally, it has been noted that using vascular imaging tools before a procedure is especially successful in treating paediatric patients and people with impaired vascular structure who are getting intravenous chemotherapy. These tool enables the viewing of veins using infrared rays. The visibility of human vein patterns on the periphery in conditions of normal visible light is very low. Near-Infrared imaging techniques can fix this. Mechanical scanning systems were used in the early days of infrared imaging to cover the full field of view with a single element detector or linear array. These systems moved the line of sight in the X and Y directions. The automatic cannula injector is typically used in medical settings such as hospitals, clinics, and emergency rooms, where there is a need for a rapid and efficient method of delivering fluids or medications to a patient. It can also be used for patients who require regular injections, such as those with chronic medical conditions.

Overall, the automatic cannula injector can help to improve the safety, accuracy, and efficiency of medical procedures, while also reducing the discomfort and pain associated with traditional injection methods. These technologies offer sev-eral advantages over traditional methods, including improved accuracy and precision, reduced discomfort for the patient, and increased efficiency for healthcare professionals. They are particularly useful in situations where patients have difficult-to-find veins, such as those with obesity or vascular disease, or in emergency situations where time is critical.

However, it is important to note that these technologies are not always foolproof and should always be used in conjunction with clinical expertise and careful patient assessment. Proper training and ongoing education are essential for healthcare professionals using these technologies to ensure safe and effective use.

II. Related Works

Vein detection is one of the cutting-edge methods academics have created today. Due to the increasing incidence of scam and counterfeit operations and the advancement of technology, recognition has now taken on a major role.We will examine hand vein authentication in this [1] work. Even identical twins who are symmetrical have different vein patterns, making each person distinctive. They are organic characteristics that remain constant over time. Since near infrared rays are used to extract the vein pattern, these veins cannot be seen with the naked eye and are therefore difficult to copy and steal. Palm vein imaging is one of the technologies that has the best chance of living up to the strict security requirements of contemporary privacy legislation for very sensitive systems.Four stages usually make up the palm vein authentication process: image acquisition, preprocessing, feature extraction, and feature matching.

Recently, interest in the finger-vein recognition technique has grown. It is a cutting-edge method for biometric and personal identification that recognises individuals by their distinctive finger-vein patterns, the first precise area to be recognised. It processes information quickly and accurately. Due to the increased focus on privacy protection, safer alter-natives to vein biometrics are also produced that are resistant to forgery, harm, or changes over time. Because fingerprint identification uses small, inexpensive, and difficult-to-copy devices, it has advantages. The techniques used in the work [2] to address prior finger-vein recognition methods, including image acquisition, pretreatment, vein extraction, and matching, are based on the findings of other researchers.

To solve security issues, biometric identity studies a per-son's physiological and behavioural characteristics.These sys-tem's identifiers include the human finger, vein, iris, palm, and many others.The most commonly accepted biometric system includes a finger vein as one of its traits.The different feature extraction techniques for identifying finger veins are reviewed in the work [3]. The acquisition of finger vein images, pre-processing, and feature extraction make up the majority of the existing work, which is functionally explained and compared in these three sections.

Injecting stem cells directly into the spinal cord may be beneficial, according to recent advances in the area of cellular therapeutics.Open surgery or a shot that is MRI-guided are both necessary for injections. Direct spinal injection faces major challenges due to needle positioning during MRI imag-ing because of the interphase space and small target region. To speed up procedures and improve positioning accuracy, a robotic needle positioning device using MRI guidance has been developed. The linear piezoelectric motors of the robot instantly control a parallel plane positioning mechanism. Feed-back is given throughout the teaching procedure using MRI. This system has been discovered to have repeatability down to 51 micrometres.The imaging modality limits the needle endpoint error, which is verified to 156 micrometer [4].

High-precision force feedback to the surgeon in robot as-sisted tele-interventional surgery is still a major problem.In the algorithm [5], We developed a brand-new spring-based haptic force interface and haptic robot-assisted catheter working system. When used in conjunction with a closed-loop force adjustment device, the haptic force interface is capable of providing precise force input. A collision protection function with a proximal-force based collision detection algorithm was proposed to improve surgical safety. Absence of an accident results in transparency of the teleoperated system. The results demonstrated the viability of the haptic robot-assisted collision safety feature catheter operating system.

The work [6] develops an idea of wearable and portable dialysis devices that could potentially improve patient quality of life by allowing them to continue with their daily activities of life while undergoing dialysis.This type of device would allow patients to have more flexibility and independence in their daily lives, as they would not need to be tethered to a traditional dialysis machine in a clinic.

Near Infrared to Visible Vein Imaging via Convolutional Neural Networks and Reinforcement Learning is another vein imaging technique presented in the algorithm [7]. By utilizing near infrared imaging we can see the subcutaneous vasculature that is not visible as far as the visible spectrum is concerned. By using U-Net-based network architecture and the Frangi vesselness filter NIR vein segmentation is done.

Digital image correlation is one of the useful technology in medical industry. The algorithm [8] presents the results of research aimed at detecting skin micro shifts caused by pulsation of the veins. The pulsation of veins can cause minor shifts in the position of the overlying skin, which is known as skin micro shifts. These shifts are often visible in areas where veins are located close to the surface of the skin, such as the wrist or neck. The degree of micro shifts can vary depending on factors such as the size and depth of the vein, the elasticity of the skin, and the amount of pressure or movement in the surrounding tissue. While skin micro shifts are generally considered a normal physiological phenomenon, they can be a cause for concern if they are accompanied by other symptoms or if they occur suddenly or frequently. If you are experiencing skin micro shifts or other unusual symptoms, it is important to speak with a healthcare provider to determine the underlying cause and appropriate treatment.

Service robots are increasingly being used in healthcare sectors to support various tasks and services, including patient care, hospital logistics, and medical research. The work [9] presents a review of various types of robotic technologies and their uses in the healthcare sector Service robots can improve efficiency, reduce costs, and enhance patient care, there are also concerns about their impact on human interaction and the potential for errors or malfunctions. As with any new technology, it is important to carefully evaluate the benefits and risks of service robots in healthcare and ensure that they are integrated safely and effectively into existing systems and workflows.

A Magnetically Navigated Microcannula for Subretinal In-jections is a medical device used in ophthalmology to perform precise and minimally invasive injections into the subretinal space of the eye which is presented in the algorithm [10]. The device consists of a small, flexible microcannula with a magnetic tip and a magnetic field generator that allows for precise and targeted delivery of medication or gene therapy.

In the work [11], we propose an efficient scale invariant fea-ture transform for palm pattern recognition. The scale invariant feature transform (SIFT) is a popular feature extraction method used in computer vision for object recognition and image matching. It is also used in palm pattern recognition to extract features from palm images for identification purposes. The experimental results show that SIFT-based palm recognition systems can achieve high recognition accuracy and robustness to variations in palm patterns.

Vein Recognition Based on Convolutional Neural Networks: The algorithm [12] proposes a new vein recognition method based on convolutional neural networks (CNNs).CNNs are a type of deep learning algorithm that is inspired by the structure and function of the visual cortex in the human brain. CNNs are powerful feature extractors that can automatically learn discriminative features from raw data, such as images, without the need for manual feature engineering. CNNs have been applied to various computer vision tasks, including object recognition, image classification, and face recognition.

The design and control of a robotic arm using stepper motors for autonomous inspection applications is reviewed in the work [13]. The arm is designed to be lightweight and portable and can be used for inspection tasks in confined spaces. The first step is to design the robotic arm, which includes selecting the type of arm, determining the number of axes, and selecting the type of motors. In this case, stepper motors are chosen due to their precise and repeatable motion. The development and control of a robotic arm for autonomous inspection using stepper motors involves a combination of mechanical, electrical, and software engineering skills. It is an exciting and challenging field with many potential appli-cations in industries such as manufacturing, construction, and medicine.

One relevant algorithm [14] on the topic of Position-Based Visual Servo Control of Dual Robotic Arms with Unknown Kinematic Models is Position Based Visual Servo Control of Dual Robotic Arms With Unknown Kinematic Models his paper proposes a method for controlling two robotic arms using visual feedback without relying on accurate knowledge of the arms kinematic models. The approach is based on a position-based visual servo control scheme that incorporates a dynamic model of the robot and a robust adaptive controller to handle uncertainties in the system

A relevant work [15] on the topic of Robotic Arm Grip-per Mechanism provides a comprehensive review of robotic arm gripper mechanisms, including their classification, design principles, and applications. The paper also presents various applications of robotic arm gripper mechanisms, including manufacturing, assembly, medical, and space exploration. The authors analyze the challenges and requirements for each ap-plication and discuss the corresponding design considerations for the gripper mechanism.

III. PROPOSED METHOD

Finding the vein's location is crucial for the doctor or nurse to assist the patient in the medical profession.In their initial experiments, many of them have trouble finding a vein and inserting a syringe into a patient's arm. In the second trial, it will make the patient feel insecure. A number of problems, including skin swelling, rashes, damage to bones and nerves,

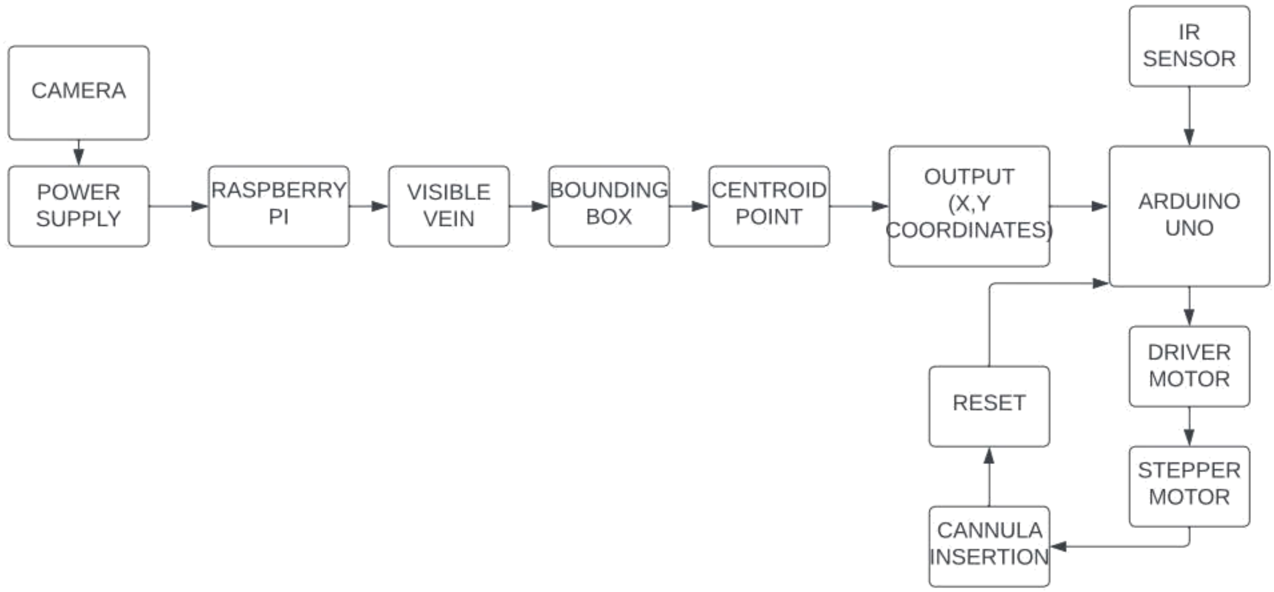

Fig. 1. Block diagram

blood clotting reactions, the appearance of black spots, dark-ening of veins from peripheral venous scarring, and arterial damage that can result in haemorrhaging and gangrene, can be brought on by improper intravenous injection administration. A device that can pinpoint the precise position of a needed vein becomes extremely important in such circumstances.

Here, an automatic injecting device with vein detection is offered as a solution to this problem. The vein can be instantly detected by this device, which can then inject a cannula into the desired vein. A modified near-IR camera is used to record the image, which is then processed to identify the vein through the use of bilateral filters, CLAHE, and grey scaling. In order to preserve edges while decreasing noise and smoothing out images, bilateral filtering is used. CLAHE is an adaptation of Adaptive Histogram Equalization (AHE) that addresses the issue of contrast over-amplification.

Instead of processing the complete image, CLAHE works with discrete sections of it called tiles. The artificial borders are then eliminated by combining the adjacent tiles using bilinear interpolation. We can also use CLAHE on colour pictures; typically, this is done on the luminance channel, and the outcomes are much better for an HSV image after only adjusting the luminance channel than they are for a BGR image after adjusting all the channels.

The centroid of the bounding box determines the position of the vein. The motion model and the appearance model are two models that can be combined to represent the tracking procedure. The motion model keeps track of the object's move-ment's speed and direction, enabling it to forecast the object's future location based on the data it has just been given.While using online training, the bounding box is manually defined and the classifier lacks training data, using pre-trained clas-sifiers would automatically determine the coordinates of the bounding box containing the object. Single-object tracking and multi-object tracking algorithms are two distinct types of tracking algorithms. The tracker we used in this case is called KCF, and it combines the BOOSTING and MIL algorithms.

The idea behind the technique is that a collection of images pulled from a "bag" using the MIL method has a lot of overlap. KCF is sufficiently high speed and accuracy, stops tracking when the tracked object is lost and it is inable to continue tracking after the loss of the object. Objectives of tracking: 1) Tracking is faster than detection. 2)Tracking is more stable. 3)Tracking provides more information. The determined vein is considered as the injecting point. This point is taken out in the form of coordinates i.e, x and y. We now have two coordinates out of three required for positioning the cannula. These coordinates are taken out as the output from the raspberry pi and given as the input to arduino uno.

Raspberry Pi can be a good choice for automatic vein detection and cannula insertion due to its low cost, small size, high performance, open-source software, and ease of integration. Despite its low cost and small size, the Raspberry Pi is a powerful computing platform that can handle complex machine learning algorithms used in automatic vein detection and cannula insertion systems. An IR sensor is used to measure the height from the cannula to the hand i.e, taken as the the third coordinate and given to the arduinouno. Arduino uno is the main controlling unit that controls the stepper motors and server motors. The Arduino is a microcontroller platform that is widely used in the field of embedded systems. The Arduino can be used to control a variety of sensors, including infrared and ultrasonic sensors used in vein detection. The Arduino can be used to control actuators such as stepper motors and servos used to control the movement of cannulas and other mechanical components.

After recieving the three coordinates as the input the arduino uno converts these coordinates which is in the form of pixels to steps using the equation D= 1.76*m, where m is the pixel value. These steps are given to driver motor which will control the stepper motor. The server motors are interconnected using a aluminuim frame and a rail type structure. While the driver motor gives informations to stepper motor, these will allign in a particular position where cannula should be inserted. The setup of automatic cannulaninjector is shown in figure 1.

High accuracy can be achieved through a combination of advanced imaging techniques, machine learning algorithms, and robotic control.Advanced imaging techniques such as infrared (IR) and near-infrared (NIR) imaging can be used to capture high-resolution images of veins and surrounding tissue. These images can be processed to enhance contrast and eliminate noise, making it easier to identify veins. Robotic control can be used to guide the cannula insertion process, ensuring precise placement in the vein. This minimize the risk of incorrect positioning of the cannula.

Robotic integration improves the precision and speed of cannula insertion. By integrating robots into the system, the in-sertion process can be automated, reducing the need for human intervention and improving the reliability of the procedure.

IV. Experimental setup and Results

The device is capable of automatically detecting the vein and injecting cannula to the selected vein. A modified near-IR camera is used to record the image, which is then processed to identify the vein through the use of bilateral filters, CLAHE, and grey scaling.In order to preserve edges while decreasing noise and smoothing out images, bilateral filtering is used. Figure 2 displays the final picture.

CLAHE is an adaptation of Adaptive Histogram Equal-ization (AHE) that addresses the issue of contrast over-amplification. Instead of processing the complete image, CLAHE works with discrete sections of it called tiles. The artificial borders are then eliminated by combining the adjacent tiles using bilinear interpolation. The position for injecting can be determined by using bounding box (Shown in figure 3).

The centroid of the bounding box determines the position of the vein as shown in figure 4. The motion model and the appearance model are two models that can be combined to represent the tracking procedure.The motion model keeps track of the object's movement's speed and direction, enabling it to forecast the object's future location based on the data it has just been given. The appearance model is also in charge of figuring out whether the item we've chosen is in the frame. When using pre-trained classifiers, the bounding box's coordinates would be calculated automatically; however, when using online training, the bounding box is explicitly specified and the classifier has no training data other than what it can gather while tracking the object.

The idea behind the technique is that a collection of images pulled from a "bag" using the MIL method has a lot of overlap. Applying correlation filtering to these regions enables highly accurate tracking of an object's motion and future location prediction.When the tracked object is lost, KCF stops tracking and is unable to resume tracking after the object is lost. It is adequately fast and accurate. The determined vein is considered as the injecting point which is shown in figure

4. This point is taken out in the form of coordinates i.e, x and y. We now have two coordinates out of three required for positioning the cannula.

Fig. 2. Visible veins after image processing

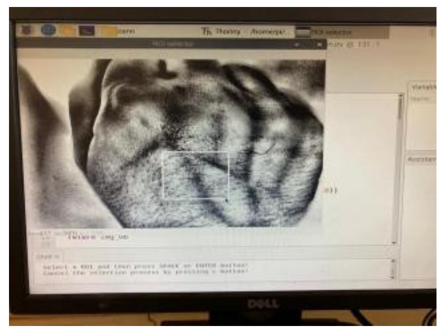

Fig. 3. Selected vein

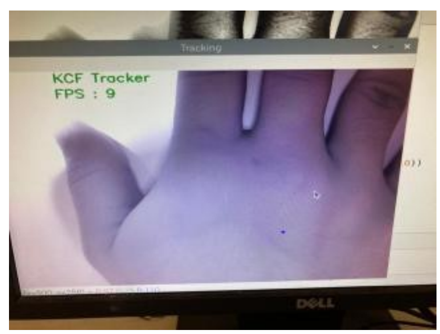

Fig. 4. Point to be injected

These coordinates are taken out as the output from the raspberry pi and given as the input to arduino uno. An IR sensor is used to measure the height from the cannula to the hand i.e, taken as the the third coordinate and given to the arduino uno. Arduino uno is the main controlling unit that controls the stepper motors and server motors. After recieving the three coordinates as the input the arduino uno converts these coordinates which is in the form of pixels to steps

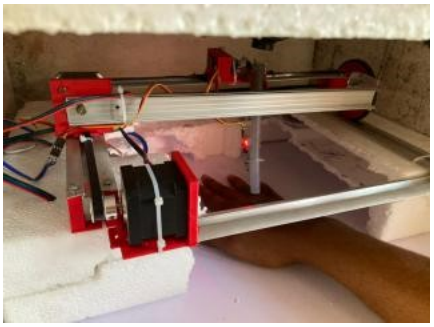

Fig. 5. Cannula inserted to the point

using the equation D= 1.76*m, where m is the pixel value. These steps are given to driver motor which will control the stepper motor. The server motors are interconnected using a aluminuim frame and a rail type structure. While the driver motor gives informations to stepper motor, these will allign in a particular position where cannula should be inserted. Cannula inserted to the point is shown in figure 5.

V. Conclusion and Future Scope

Automatic vein detection and cannula insertion technolo-gies are increasingly being used in healthcare settings to aid in the placement of cannulas and reduce discomfort for patients. These technologies offer several advantages over traditional methods, including increased accuracy and preci-sion, improved patient comfort, and increased efficiency for healthcare professionals. The vein can already be distinguished from other body networks using image processing techniques. On the system median, the RGB camera with similar data performs 13:04 percentage better and 6:22 percentage better on the threshold adaptive. However, the input of a decent vein image determines the image processing technique. Several vein enhancement techniques, including image negative, grey level slicing, histogram equalisation, contrast stretching, Laplacian sharpening, unshapely masking, high boost filtering, and his-togram equalisation of high boost filter, are used to accurately identify vein pattern in the presence of unwanted noise and indistinct state. The exact alignment of the needle with the location of the targeted vein is ensured by a clever feedback system using live video. The system is safe for people because of numerous trials that produced extremely accurate vein position detection and needle alignment. These trials were confirmed by skilled medical professionals. The system is built to operate automatically, accurately, and precisely while utilising the data given to it.

Collecting high-quality vein images and clinical data from a diverse patient population can help to improve the accuracy and reliability of vein detection algorithms. This can involve using a variety of imaging techniques, such as ultrasound and collecting data from patients with different skin types, ages, and medical conditions.The system can be developed for different inclination degrees in the future.To ensure that an injection is painless, efficient, and secure, speed control is crucial. Particularly in areas with limited access to medical care, the designed system can greatly facilitate and improve the health sector. It can be very helpful for elderly persons who are dependent and for mass vaccination. Additionally, it can go to locations where sending carers would be dangerous. The developed cost-effective technique will, in the end, provide a comprehensive solution to a number of issues.The system can be designed with feedback mechanisms that provide real-time information about the position of the cannula relative to the vein. This information can be used to adjust the insertion process in real-time, improving accuracy and reducing the risk of complications. However, it is important to note that these technologies are not a substitute for clinical expertise and proper patient assessment. They should always be used in conjunction with careful patient evaluation, and healthcare professionals using these technologies should receive proper training and ongoing education to ensure safe and effective use. Overall, automatic vein detection and cannula insertion technologies have the potential to greatly improve the quality of care for patients, and their use is likely to become increas-ingly widespread in healthcare settings in the coming years.

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