

Application of a Robotic Arm in Assisting Disinfection Before Venipuncture Needle Insertion

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***Abstract---** Robots have been widely used in various medical practices ranging from complicated neurosurgery to patient rehabilitation in recent years. They are playing ever more important roles in medical institutions and of great help to medical staff in the jobs they are doing. However, in one of the most frequently performed procedure, venipuncture, application of robots or other automatic devices remains largely unseen. The procedure, though may not be as complicated as a neurosurgery, still requires trained and experienced personnel and is inherently risky. Studies have shown that percutaneous injuries are the most common occupational injuries for medical personnel and the costs are high for medical institutions. Venipuncture consists of several steps. In this paper, the application of a robotic arm in assisting disinfection before needle injection is studied. The ultimate goal is to develop a fully automatic venipuncture system.*

***Index Terms**—medical robotics, automatic venipuncture, arm disinfection, blood draw.*

I. INTRODUCTION

Early robots were mostly used in manufacturing industries, doing jobs which are repetitive, labor intensive in highly risky, harsh environment. These robots performed the work according to recorded information provided by human engineers. They were incapable of adapting to volatile situations. However, with the rapid increase in computer processing speed, combined with the use of various types of sensing devices, robots began to be able to detect external changes, and make the proper choice of action by themselves. In recent years, in addition to a large number of applications in the industry, they have extended to wide-ranging tasks, such as service robots, educational robots, medical robots, etc. Robots began to go out of the factory and into our daily life. Employment of robotic arms in medical surgery were first studied more than 40 years ago [1]. Since then, many medical robots have been developed, from complicated neurosurgery to patient rehabilitation [2], they are becoming indispensable to many medical practitioners. However, in one of the most frequently performed procedure, venipuncture, application of robots or other automatic devices remains largely unseen. This study looks into the possibility of applying a robotic arm in one of the important steps of venipuncture, namely sterilization. It can then be integrated into a fully automatic venipuncture system.

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II. PROBLEM STATEMENT

Although robots have been introduced to medical professionals for many years, not performing any task on their own, they remain essentially extensions of human senses and functions [3]. All the actions still need to be performed by humans. Nowadays, with the phenomenal progress of hardware and software development, studies are being made to incorporate robots into medical practices as more active assistants [4]-[9]. Venipuncture is one of the most commonly performed procedures in medical institutions. There are estimated 2.7 million practices per day in the U.S. alone [10]-[11]. The procedure, though may not be as complicated as a neurosurgery, still consists of many steps [12]. It requires trained personnel to execute [13]-[15]. It is also inherently risky, studies have shown that percutaneous injuries are the most common occupational injuries for medical personnel [16]-[18], and the resulting costs are high [19]-[21]. In summary, a venipuncture procedure has the following characteristics:

- 1) It is mostly a repetitive operation but subject to several variables, e.g., a patient's age, skin condition, vascular position, for which the operation has to be adjusted on sight.
- 2) Unlike other medical operations performed in a very controlled and closed environment, venipuncture is usually done in a much more volatile environment.
- 3) It is generally carried out by one health worker without the help of any other medical professional, automated or semi-automated device.
- 4) There is a certain degree of risk to the patient, health worker or even others.
- 5)

In recent years, efforts are made to develop an automatic system to eliminate the risks involved in venipuncture, reduce the burden of health workers, and improve the efficiency [22]-[25]. Any automatic system under development basically consists of an image processing system and a robotic arm. The image processing system capture and analyze the vessel images of the arm and decide the best point for needle insertion. The information is then passed to the robotic arm or other mechanical components which then perform series of motion to complete the task. However, these devices remain in laboratories and have not been used in clinical situations. Even if they can be put into clinical use, they all emphasize on the execution of needle insertion, not covering all the phases of drawing blood as stated by WHO guidelines [12]. This study looks into the possibility of applying a robotic arm in one of the important steps of venipuncture, namely disinfection. It can then be integrated into a fully automatic venipuncture system.

III. EXPERIMENT SETUP

A. Hardware

A robotic arm is used for grasping a cotton ball soaked in a 70% solution then rubbing the venipuncture site. The arm consists of a base, an upper arm, a lower arm and an end effector. The structure of the arm is shown in Fig. 1 [26]. Submit your manuscript electronically for review.

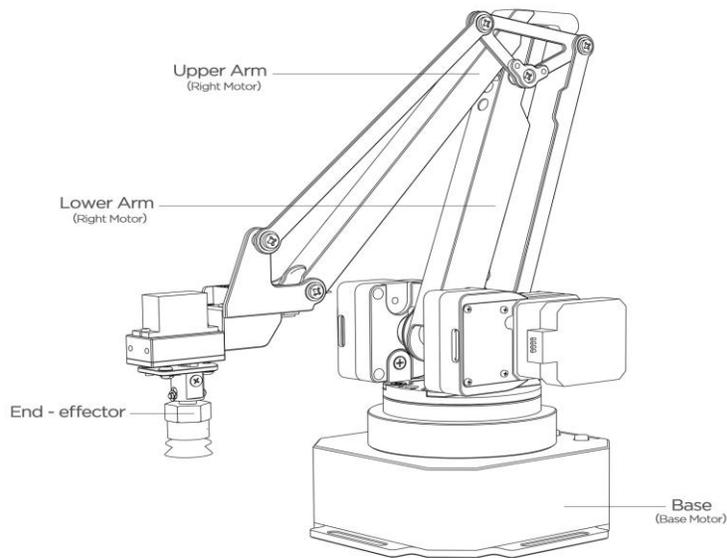


Fig. 1 The structure of the employed robotic arm

The specifications of the robotic arm are shown in Table I.

Table I Specifications of the robotic arm

Weight	2.2 kg
Degrees of Freedom	4
Repeatability	0.2 mm
Max. Payload	500 g
Working Range	50 mm ~ 320 mm
Max. Speed	100mm/s

A gripper, Fig. 2 [26], is installed on the end, Fig. 3 [26], for actually grapping a cotton ball.

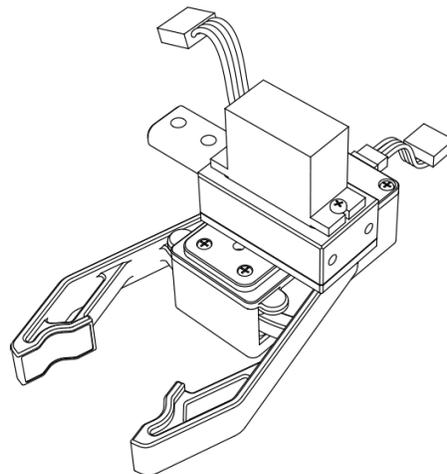


Fig. 2 The gripper used for grapping a cotton ball

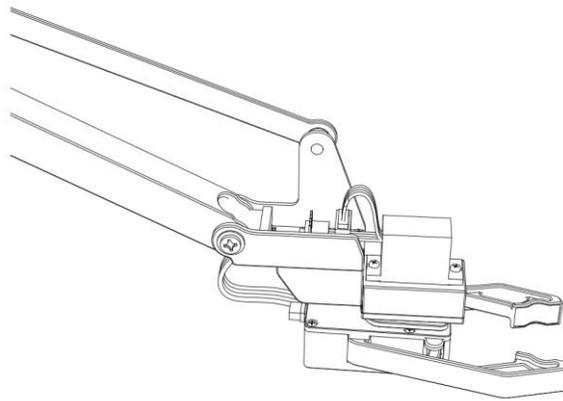


Fig. 3 The gripper installed on the end of the robotic arm

A cotton ball snap tube is designed, as shown in Fig. 4, to allow cotton balls freely fall to the bottom but not fall through.

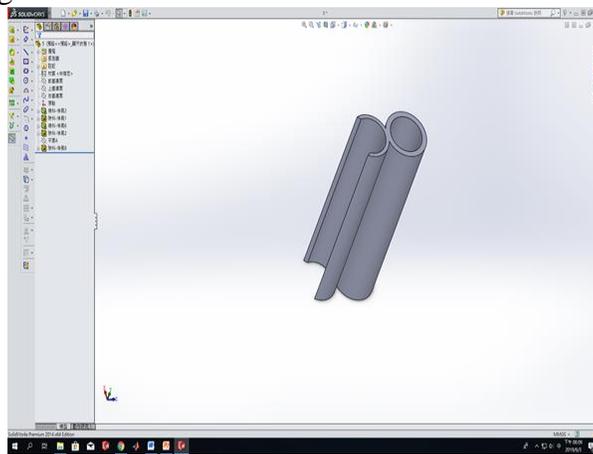


Fig. 4 The CAD model of the designed cotton ball snap tube

It is then manufactured by 3D printing, Fig. 5 (a), and placed on a platform built for venipuncture, Fig. 5 (b).



(a)



(b)

Fig. 5 (a) The manufactured cotton ball snap tube (b) The combine platform and tube

An artificial skin shown in Fig. 6 is used to mimic the human skin and blood vein distribution. After grabbing an alcohol soaked cotton ball from the ring, the robotic arm will rub the artificial skin to simulate actual disinfection process.



Fig. 6 An artificial human skin

B. Software

The robotic arm can be implemented by uArm Studio software. The software includes a visual programmer, a hand-guiding teaching mode, 3D printing, drawing and engraving operations. The visual programmer is used to control the robotic arm in this study. It can be programmed by means of drag-n-drop as shown in Fig. 7.

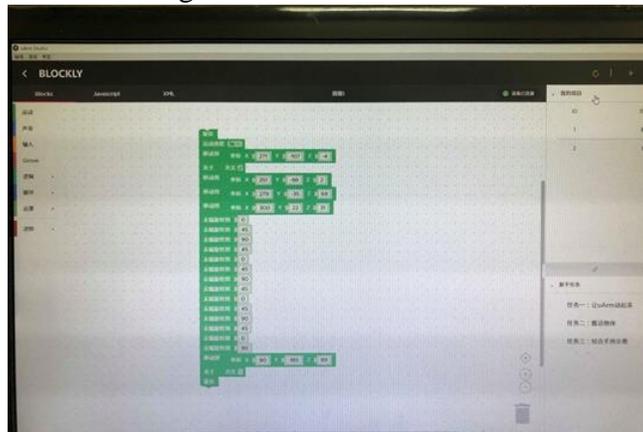


Fig. 7 The visual programmer used to control the robotic arm

II. EXPERIMENT RESULT

The cotton ball snap tube is attached to a venipuncture platform. Cotton balls soaked in alcohol are placed in the tube. The tube is designed so that a cotton ball can freely fall to the bottom but not fall through it. The robotic arm is programmed to first grabbing a cotton ball from the tube, Fig. 8(a), then rubbing against the artificial skin to simulate the disinfection process, Fig 8(b).

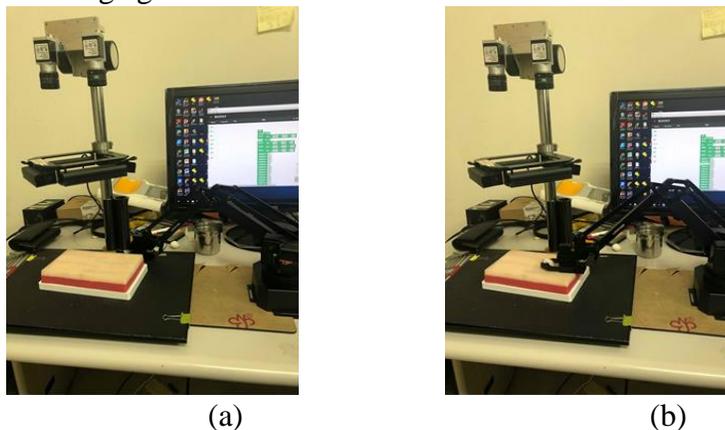


Fig. 8 (a) Grapping a cotton ball (b) Rubbing the artificial skin

The arm then drops the used cotton in a can, Fig. 9(a), then grab next cotton ball if necessary, Fig 9(b).

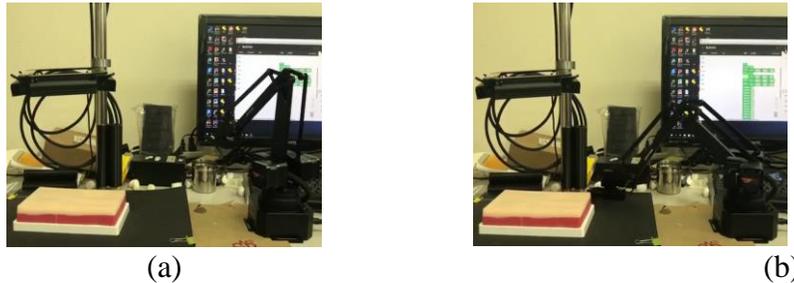


Fig. 9 (a) Dropping the cotton ball (b) Grabbing next cotton ball

III. CONCLUSION

The application of a robotic arm in assisting disinfection before needle injection is studied. It is shown that the arm can simulate the disinfection process by combining suitable hardware and software. It may be integrated into a fully automatic venipuncture system. The proper point for needle insertion can be first identified by an automatic needle insertion point recognition system, e.g., [27], the information can then be passed to the robotic arms to carry out proper disinfection procedure and needle insertion. A fully automatic venipuncture system will greatly reduce the work load and risks of health workers, lower costs and increase efficiency in medical institutions.

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