AN AUTOMATIC LASER ACUPUNCTURE SYSTEM

[1]CHIH-YUNG HUANG, [2]SHU-CHEN CHANG, [3]CHIH-YU WANG, [4]TZU-HAO TSAI, [5]YI-AN LIOU

[1,3,4,5]Department of Biomedical Engineering, I-Shou University, Kaohsiung, Taiwan
[2]Department of Hospitality Management, Tajen University, Pingtung, Taiwan
E-mail: sos2364@gmail.com, doris@tajen.edu.tw, crab@isu.edu.tw

Abstract— The purpose in this research is to develop an automatic laser acupuncture system with the combination of machine vision, robotic arm, and a laser acupuncture instrument. After we selected several acupuncture points and marked it, the system would track the signs through the features and calculate the coordinates. The camera coordinates were converted into mechanical arm coordinates and transmitted to the robotic arm. According to the coordinates of the camera, the robotic arm could be positioned automatically after moving to the position of the acupuncture point. The robotic arm would be fixed and start the laser acupuncture treatment. With this system which we research and develop, users can choose acupuncture points and calibrate them. Doctors can use laser acupuncture with this system to relieve their fatigue caused by repeated acupuncture patients. It makes the doctors to focus more on the patient's treatment, and effectively improve the quality and efficiency of acupuncture treatment.

Index Terms— Laser acupuncture, Automatic, Machine vision, Robotic arm.

I. INTRODUCTION

Recently, automation has become a trend in this world. Many researchers apply automation to the variety of places, such as an automatic fruit harvesting system by D. Font and other people in 2014. It combined a low cost stereovision camera and a robotic arm placed in the gripper tool. The stereovision camera was used to estimate the size, distance, and position of the fruits whereas the robotic arm was used to mechanically pick up the fruits.[1] There have been many studies that have used robotic arms for rehabilitation. In this study, we hope to effectively reduce the burden of medical staff and improve medical efficiency by using automation in medical care.

Laser acupuncture has four following advantages over traditional acupuncture. Firstly painless, there is little pain in the whole treatment process when laser acupuncture uses low-intensity lasers to stimulate the acupoints of acupuncture. Secondly noninvasive, laser acupuncture is different from traditional acupuncture, it does not leave a wound on the skin surface of the body. Thirdly asepsis, there is no risk of infection caused by incomplete sterilization because laser acupuncture does not have a needle into the skin condition.[2] Lastly time-saving, laser acupuncture compared with traditional acupuncture, it is more convenient and faster for treatment. However, there are also have limits to laser acupuncture, such as the laser acupuncture system used in this study. It cannot be fixed to the patient's body like traditional acupuncture, so that the treatment will be limited and doctors have a lot of burden because doctors have to hold the laser needle at the whole time. The other limit is that acupuncture for the user identity of relatively stringent. If the points of stimulation are not in the correct position, the effect will sell at a discount greatly. Therefore, it must have the relevant experience of traditional Chinese medicine acupuncture users. In this study, we are looking forward to reducing the burden of physicians and improving the efficiency and quality of the medical care through this system.

This research chooses to use the machine vision which has developed rapidly in recent years and the technology is mature. In the application of machine vision, many scientists have carried out relevant experiments and published literature, such as the research by J. Wang and other people, which was intended for a super-size 3 dimensional scaling events sensing and positioning system based on binocular stereo vision. In their research result, position data obtained in real time for aircraft and vehicles on the airport surface could be presented to an Advanced Surface Movement Guidance and Control System (A-SMGCS).[3] The other research by P. Zhao and other people was a novel measurement scheme for a three dimensional (3D) object's surface boundary perimeter. In their research, a binocular stereo vision measurement system with two CCD cameras was devised to obtain the detected 3D surface boundary of the objects.[4] Light usually marching through a variety of media, such as glass, water, air. However, these media will affect the image quality and change the light path. To solve this problem, H. Du and other people put forward a new method of object reconstruction for the glass flume, and it is based on computer vision theory and laws of refraction. At present, the machine vision is widely used in various fields. In this study, we intend to assist laser acupuncture by using machine vision to achieve the automation of laser acupuncture system. The laser acupuncture instrument is arranged on the mechanical arm, and the depth camera is used to shoot and calibrate to obtain the point position.

Three-dimensional measurement is a vital point in the

field of machine vision, and it is widely used in various fields (e. g. , the three-dimensional map construction, the object recognition, the distance measurement, and the spatial measurement). However, the most significant problem of 3D measurement is its accuracy. In order to confirm the accuracy of 3D measurement, it is very essential to correct the camera before we use it. Camera calibration has great influence on the accuracy of stereo vision whereas the camera calibration is to determine the relationship between the 2D coordinates positions on the image and the 3D world coordinates of the objects.

II. MATERIALS AND METHODS

A. Research materials

A.1 Emulated laser-acupuncture system

In this study, we used the emulated laser-acupuncture system which was self-made in our laboratory, and it could achieve the effect which was similar lift and thrust in traditional acupuncture treatment. This system adopted NI myRIO as the core of controller, which was driven and controlled with LabVIEW software. We put power setting, acupuncture manipulation, and force parameters within NI myRIO. At the same time, we could control the depth (focus position), force (laser light intensity), acupuncture speed, and acupuncture duration. It used the touch panel as the control interface of the human-computer interface so that users could set the manipulation of the needle and the acupuncture duration. After setting the required function, we could implement acupuncture by start key.

A.2 Depth camera

The depth camera in this research was the RealSense™ Camera SR300, which was produced by Intel. The typical camera made the three-dimensional space image of the real world was stored as a two-dimensional XY axis plane picture, however, the this camera stored 3D spatial information directly by its mutual cooperation of three lenses. These three camera lenses were respectively traditional camera lens, infrared laser lens, and infrared camera lens. They inferred depth of field (Z axis) by detecting the infrared reflection of an object in front of it.

A.3 DOBOT Magician

In this research, we used the DOBOT Magician which was produced by the Shenzhen Yuejiang Technology Co. Ltd. It was a four-axis robot arm with built-in coordinate system and an effective load of up to 500 (g). It could communicate through USB/Wifi/Bluetooth.

The reason for choosing it was that it had a variety of development environments to select, and users could choose their own more familiar with the programming language for development. Furthermore, it had its own coordinate system, could reduce the difficulty of development.

A.4 Python

Python was a high-level programming language, and it also was a general-purpose programming language. It was widely used in various fields. It was created by Guido van Rossum, and its first edition was released in 1991. Python was a literal language whose design philosophy emphasizes code readability and syntax simplicity. On the software side, we chose to use Python for control, because it was fast in coding, simple in syntax, and reduced development time.

A.5 OpenCV

It was initiated and developed by Intel Corporation and released under BSD-authorized terms. It could be used for free in the research field. OpenCV could be used to develop real-time image processing, computer vision, and pattern recognition programs.

A.6 Checkerboard

It was used for camera calibration of black and white checkerboard squares, we set the length and width of the squares as 20mm. It is shown in figure 1.

In this study, we used the internal and external parameters which were calculated by various angle photos (A~G) to correct the angle photos (H) which was used in the experiment, so as to find out the corresponding relation between space and pixel coordinates.

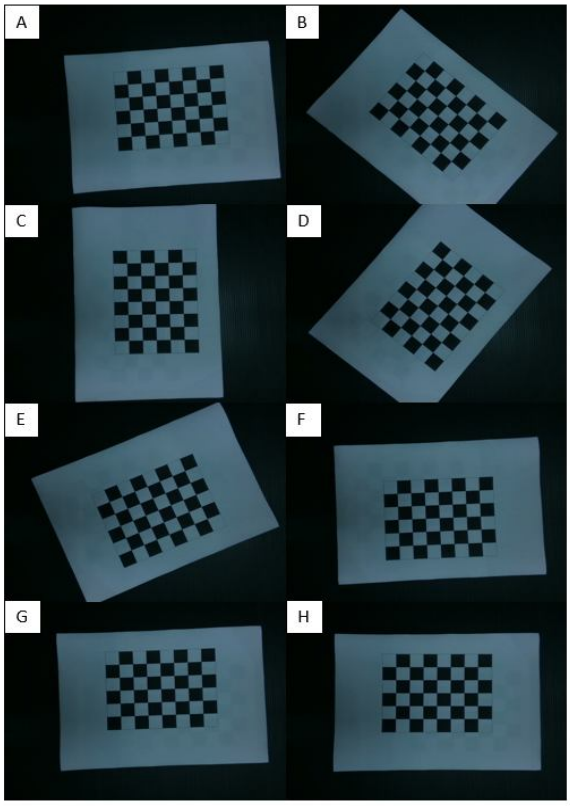


Figure 1. 6 x 8 checkerboard used in the experiment.

B. Research methods

This research project consisted of depth camera, mechanical arm and laser acupuncture instrument. The goal was to integrate the deep camera with the robotic arm and laser acupuncture instrument into an automated laser acupuncture system. This system is used for automatic positioning of laser acupuncture needles, and it could assist doctors to perform laser acupuncture when they perform acupuncture treatment on patients. Moreover, it could reduce the burden of traditional medicine physicians in repeated acupuncture treatment, and they could pay more attention on the treatment of patients.

In this study, we calibrated the camera to ensure its accuracy. Therefore, we took images of the patient with the depth camera, got the pixel points of the target acupoint from the image, and calculated its 3D world coordinates. The acupoints on the patients were marked with color by the doctors, and they could track the marked acupoints by the feature points and tracking algorithm. It transmitted the acupoint coordinates through transformation formula to the coordinate system of the robotic arm, and transmitted to the robotic arm. Therefore, the robot could perform dynamic tracking of acupuncture points on the human body. We expect to design a loop to judge whether it is located in the acupuncture points. If it was "Yes", the robotic arm would hover over the target acupoint. If it was "No", the robotic arm would continue to move to track the target acupoint. The procedure is shown in figure 2.

The movement of the robotic arm was used in this study has its limitations, and it could not extend to the whole body. Therefore, we would focus on image tracking of acupuncture points on human limbs and face.

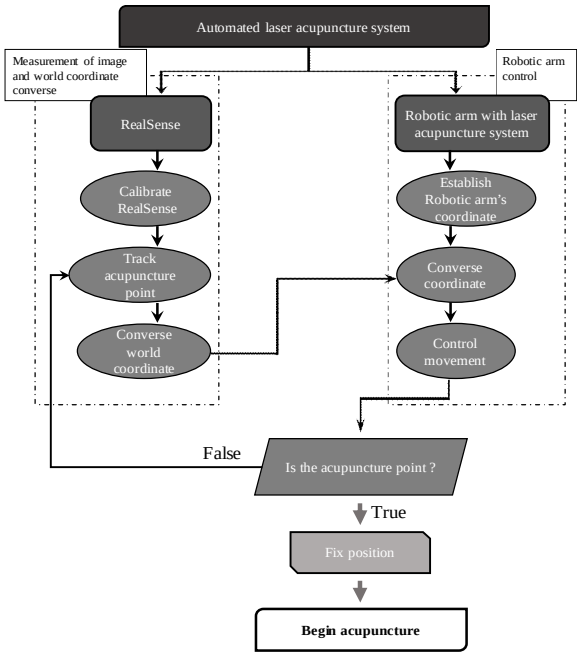


Figure 2. The procedure of an automated laser acupuncture system's experiment.

B.1 Camera calibration

Due to the problem of the camera itself, the image would be distorted when the camera took pictures. To solve this problem, the camera had to be calibrated, and this action could obtain the relationship between the 2D image and the 3D coordinates. It is shown in (1).

$$sm' = A\left[R|t\right]M' \tag{1}$$

R is the rotation matrix, t is the translation matrix, and A is the internal parameter of the camera. The internal parameters of the camera are also fixed when the focus of the camera is fixed, whereas the external parameter $\left[R|t\right]$ is that each image has a different value. By this formula, the internal and external parameters of the camera can be calculated, which will be used for distortion correction.

The IR(Infrared) Laser Projector in the SR300 camera emitted structural light. Moreover, it would be received by IR(Infrared) Camera Lens when it was reflected off the object. The structural light captured by the infrared sensor differs because the distance between the camera and the subject surface was different. The spatial information about an object's surface cuold be calculated based on these elements processed by a real image. Therefore, we could perform the depth calculation by the triangulation and distance measurement. It is shown in figure 3 and (2)-(5).

B.2 3D coordinate measurement

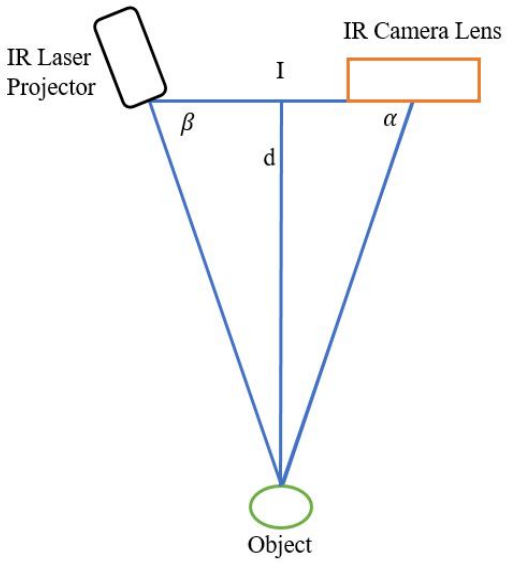


Figure 3. Schematic diagram of triangulation and distance measurement.

$$\ell = d/\tan\alpha + d/\tan\beta \tag{2}$$

$$\tan\alpha = \sin\alpha/\cos\alpha \tag{3}$$

$$\sin(\alpha+\beta)=\sin\alpha\cos\beta+\cos\alpha\sin\beta \quad (4)$$

$$d=\ell[(\sin\alpha\sin\beta)/\sin(\alpha+\beta)] \quad (5)$$

We assumed that the target dot and infrared emitter form a triangle with the sensing device, it show in (2). The target point coordinate and distance were found through the calculated target and the angle of the infrared emitter and sensing device to form the edge of the triangle. It could find the target point coordinates and distance through the triangle which was formed by calculating target and the angle of the infrared emitter and sensing device.

To find the distance, we could convert (2) into (5) by the trigonometric identity, which is (3) and (4). Therefore, the distance between the object to be measured and the lens and the offset of the image difference could be obtained, and the complete coordinates could be obtained.

B.3 Color recognition

We recognized color with HSV (Hue, Saturation, and Value). It is shown in figure 4.1. We set the HSV of the desired target color in the program, and binary the selected color. It can see in figure 4.2. The camera automatically captured the set color pixel coordinates, and conversed it.

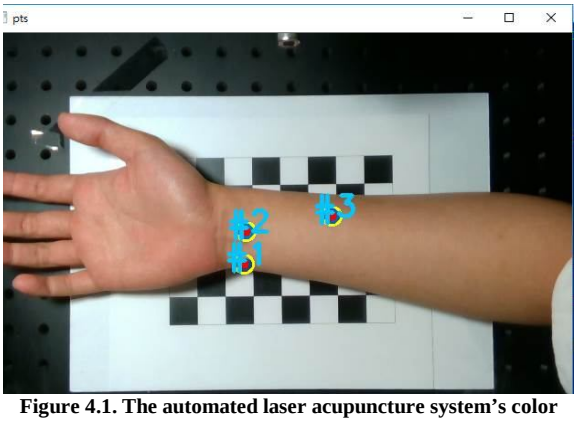


Figure 4.1. The automated laser acupuncture system's color recognition screen.

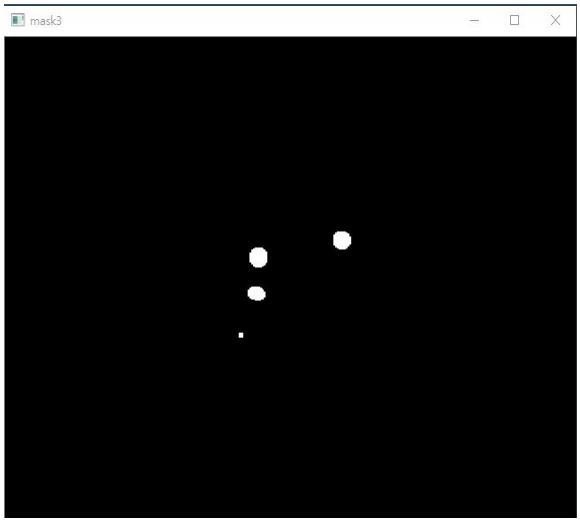


Figure 4.2. Binary image.

B.4 Coordinate transformation

In the beginning, we used interpolation (it is shown in (6) and (7)) to determine the position of the target in the spatial coordinates. There is a schematic diagram of interpolation method in figure 5. (h, i) is the position of the target, $0<h<u$, and $0<i<v$. After determining the spatial coordinates of the target position, we conducted to convert the position of the target into the coordinate system of the robotic arm. The process of conversion is shown in (7)-(12). That design could control the movement and positioning of the robotic arm. (x, y, z) is the target position in the coordinate system of the robotic arm. (D_{x0}, D_{y0}, D_{z0}) is the Dobot zero point coordinates. (W_x, W_y) is the position of the target object in the space coordinates. d_{CT}, d_{C0} respectively represents the distance between the camera to the desktop and the camera to the target object.

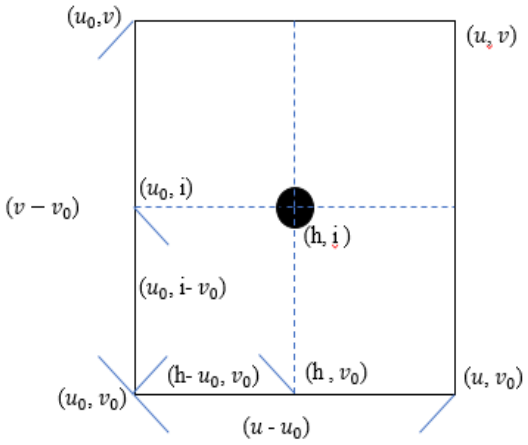


Figure 5. Schematic diagram of interpolation method.

$$a=(h-u_0)/(u-u_0) \quad (6)$$

$$b=(i-v_0)/(\upsilon-v_0) \quad (7)$$

$$W_x=W_{x0}+(W_{x1}-W_{x0})\times a \quad (8)$$

$$W_y=W_{y0}+(W_{y1}-W_{y0})\times b \quad (9)$$

$$X=D_{x0}+20W_x \quad (10)$$

$$Y=D_{y0}+20W_y \quad (11)$$

$$Z=(d_{CT}-(d_{C0}/10)+D_{z0}) \quad (12)$$

B.5 Robotic arm movement control and automatic tracking of target points

This study designed programs in Python to control the robotic arm, and the following concepts to design it:

(1) The robot arm could move from point to point in the shortest moving path.

(2) Setting up a movement path for robotic arm, and changing the height before moving.

(3) If the coordinates of the target acupoint were changed, the robotic arm could receive the new

position information on the target acupoint and change the movement path immediately. With the new coordinates as the end point, and the positioning could be carried out quickly and accurately.
(4) Setting the positioning error of acupoints within 2.5mm.

However, the control flow of the robotic arm was as follows:
(1) Enable the robotic arm to receive the coordinates transmitted by the controller.
(2) After receiving the coordinates, the robotic arm moved to the target points.
(3) When the robotic arm reached the target points, and the position was fixed.
(4) When the target acupoints position were changed, and repeating (2)-(3).

III. RESULT AND DISCUSSION

After starting the depth camera, we calibrated the camera and set up the correspondence between the camera coordinates and the world coordinates. Subsequently, we selected the acupuncture points on the computer and marked the target points. In this study, we used the depth camera to measure the coordinates and distances of the target points in the space coordinate system. This system would automatically locate the target position in the space coordinates, convert the coordinates of the robot arm, and sent the coordinates to the robotic arm in real time. When the robotic arm received the coordinates, it would move the shortest path to the correct acupuncture point location, and comply the correct acupuncture therapy. Furthermore, the system could by the depth of calculation to avoid the mechanical arm collision to the location outside the test position, i. e., automated laser acupuncture systems could be used for acupoint positioning. It can see in figure 6.1 and 6.2.

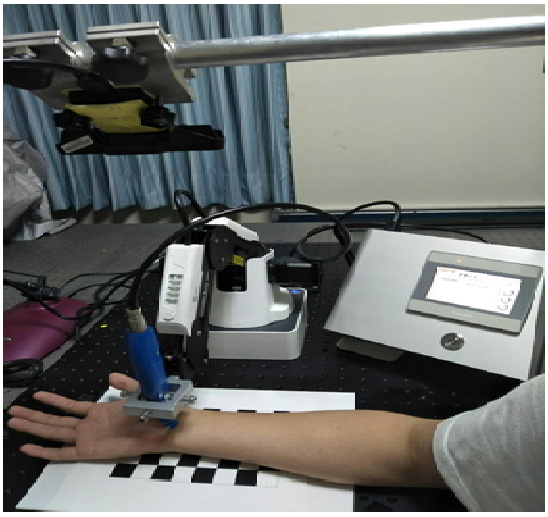


Figure 6.1. The automated laser acupuncture system.

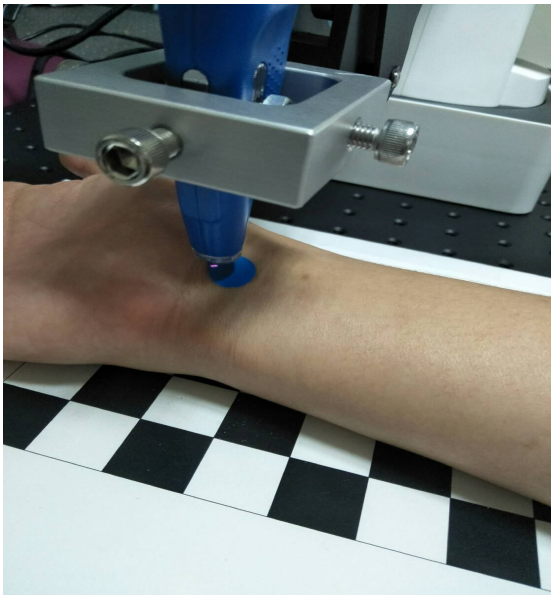


Figure 6.2. Positioning of the automation system.

By 20 times of experiments, we divided into two groups based on 40 (mm). If the distance more than 40 (mm), it defined to be long. If the distance less than 40 (mm), it defined to be short. Each group had to take five points, and test the position of the automated laser acupuncture system. In this test, we found that the horizontal and vertical distance between the position of the system and the location of the target are at an average of 4.8 (mm) and 4.7 (mm) respectively, and the distance error was larger in the far needle movement. It is shown as table 1. There was a research that the diameter of an acupoint around 5 – 8 (mm),[7] so that we intended that the horizontal error could be controlled within 4 (mm).

In this study, the horizontal average error was 4.8 ± 1.16 (mm), however, it was 3.7 ± 0.29 (mm) when it in the short distance, which was defined as < 4 (mm). As a result, we believed that the error could be reduced when we changed the long distance movement to the multiple short distance movements. On the other hand, the vertical average error is increased by 2 (mm) in advance because we did not want the needle to touch the human body directly in the design of the experiment. Therefore, it could be accepted when the actual distance was about 2.7 (mm).

Table 1. Positioning error of the automation system.

	Short distance (mm)	Long distance (mm)	All distance (mm)
Horizontal average error (mean ± SD)	3.7 ± 0.29	5.9 ± 0.52	4.8 ± 1.16
Vertical average error (mean ± SD)	4.2 ± 0.36	5.2 ± 0.52	4.7 ± 0.51

CONCLUSION

In this study, we developed an automatic laser acupuncture system which was used for automatic acupuncture. In the experiment, we found that the automated laser acupuncture could find the acupuncture points quickly that we chose. Although there was some error with the mark, the error was in the acceptable range. We will continue to validate and reduce errors in subsequent experiments, and apply this system to practical acupuncture positioning experiments.

This system can significantly improve the efficiency of the acupuncture treatment. In the future, it can be applied to the clinic of TCM, and reduce the burden of traditional Chinese medicine doctors by the system. Doctors can more focus on thinking about the patient treatment, and provide better medical quality for the patients.

REFERENCES

[1] D. Font, T. Pallejà, M. Tresanchez, D. Runcan, J. Moreno, and D. Martínez, et al., "A proposal for automatic fruit harvesting by combining a low cost stereovision camera and a robotic arm," MDPI Sensors, vol. 14, no. 7, pp. 11557–11579, July 2014.

[2] K. -F. Kuo, "Development and application of an emulated laser acupuncture system," Master's Thesis of Biomedical Engineering, I-Shou University, 2008.

[3] J. Wang, X. Wang, F. Liu, Y. Gong, H. Wang, and Z. Qin, "Modeling of binocular stereo vision for remote coordinate measurement and fast calibration," SDOL Optics and Lasers in Engineering, vol. 54, pp. 269-274, March 2014.

[4] P. Zhao, and N. -H. Wang, "Precise perimeter measurement for 3D object with a binocular stereo vision measurement system," SDOL Optik - International Journal for Light and Electron Optics, vol. 121, no. 10, pp. 953-957, June 2010.

[5] H. Du, M. -g. Li, and J. Meng, "Study on the reconstruction method of stereo vision in glass flume," SDOL Advances in Engineering Software, vol. 94, pp. 14-19, April 2016.

[6] Z. Jia, J. Yang, W. Liu, F. Wang, Y. Liu, and L. Wang, et al., "Improved camera calibration method based on perpendicularity compensation for binocular stereo vision measurement system," OSA Optics Express, vol. 23, no. 12, pp. 15205-15223, June 2015.

[7] Q. -Z. Wu, "The User's Manual For Human Body (Chinese Edition)," Taiwan, Da Guan, June, 2005.

[8] C. -Y. WANG, S. -F. YEN, S. -C. CHANG, Y. -H. CHIU, C. -C. KUO, C. -E. WU, "Implementation of laser acupuncture with lifting–thrusting through the use of mechanically immobile components," OSA Applied optics, vol. 54, no. 28, pp. E129-E135, Aug 2015.

★★★