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Innovation design and operation control method of the minimally invasive vascular interventional surgery robot system

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ABSTRACT

A novel minimally invasive vascular interventional surgery robot system is proposed. The system includes a positioning arm, a catheter interventional device and its manipulation device. Anew operation control method for the positioning arm is presented, which is to drag a six-dimensional force sensor fixed on the end of the arm. A six-dimensional force signal will be outputted and transformed into a position and orientation matrix respective to the positioning arm. A fictitious joint is added to the arm with five-degree of freedom (DOF) in accordance with certain principles to change it into a six-DOF configuration. Using the obtained position and orientation matrix to do inverse kinematic of the six-DOF mechanism, the inverse kinematic of the five-DOF mechanism can be obtained. Take these values as position control commands to the corresponding joint motors to realize the motion control of the positioning arm. A numerical example is given to verify the correctness of the proposed method. A master-slave system composed by a catheter interventional device and its manipulation device is proposed. The corresponding actions of every operation states and the master-slave control principle are given. The mapping relations between the displacement distances of the manipulation handle and the promoting finger and between the rotation angles of the handle wheel and the catheter/guide wire are described. By setting different proportionality coefficients, the multi-gear control can be realized. With the help of master-slave operational method, the doctors can do operations outside the operation room to protect themselves from radiation. Moreover, the system can realize force feedback which can help the operator to have force telepresence and to increase the sense of reality and immersion. © 2013 Trade Science Inc. - INDIA

KEYWORDS

Minimally invasive interventional surgery;
Positioning arm;
Operational method;
Catheter interventional device;
Master-slave operation.

INTRODUCTION

Cardiovascular disease is a major threat to human health all over the world. In China and even in the world, its morbidity and mortality has been head of the each kind of diseases, and the prevalence rate is 30%[1].

Minimally invasive operation with small wound, rapid recovery after operation, slight pain is gradually accepted by doctors and patients of cardiovascular disease[2]. That the robot technology is applied to the minimally invasive operationcan greatly improve the operation accuracy, reduce the labor intensity of the doctor, avoid the man-made error[3,4].

Minimally invasive interventional operation robot system includes a positioning arm, tube feeding mechanism and operating device. The positioning arm is the assisted positioning device of the minimally invasive vascular interventional robot, which can adjust the location of the operation deviceand fix position. The positioning arm includes active mode and passive mode. The each joint of the active positioning armis equipped with driving device, which has the advantageof high positioning accuracy, without the need for mechanical arm balance,but the traditional control method is too stylized, not dragged optionally, the poor ability to adapt to the environment and it can only move according to the preset program[5]. The passive mechanical arm is the mechanical arm joint without the driving device, so it needs the force to make it move. Its advantage is that it can be dragged optionally by the human. The passive mechanical arm currently used in medical field has Da Vinci system and ZEUSrobot system[6], the "Liyuan" stereotactic directional robotic system developed by Beijing University of Aeronautics & Astronautics University[7], the "Micro-hand" system developed by Tianjin University and so on[8]. But the limitation of the passive mechanical arm is that the mechanism design needs to achieve its own balance, the self-locking device, and it is difficult to make accurate position adjustment.

In view of the shortcomings of the active and passive positioning manipulator, Italy scholar proposed anactive/passive positioning arm Navi-Robot, which can be manual operation and programmed operation[9]. The reference[10] puts forward anoperation instrument positioning robot, and its each joint is equipped with a torque sensor. The operation is aided by the joint force of the robot, so it does not need pre-set trajectory programming. The mechanical arm can move optionally by the drag of any operator, so it can keep the advantage of without self-balance of the active arm, and it also has the advantages of randomness and flexibility of the passive mechanical arm operation. But because the robot movement is achieved by the joint force feedback control, it is difficult to reach the target position precisely according to the expected trajectory. Minimally invasive operation with a positioning armhas a strong ability to adapt to the environment, that is can be dragged optionally, adjust the arm posture at any time, and achieve fast locking. Therefore, this paper presents a positioning arm control method based on a kind of six-dimensional force sensor in the way of drag, to solve the problem of the main passive arm localization.

The tube feeding mechanism fixed on the end of the positioning arm is used to assist the doctor to bring the catheter, guidewire medical devices into human blood vessels to diagnose and cure. At present, many domestic and foreign institutions havebeen doing the research. Canada HANSEN MEDICAL company developed Sensei: the catheter / guidewirepushing mechanism of the vascular intervention operation robot system[11]; Catheter Robotic Incorporation developed the Amigo tube feeding mechanism[12]. These two kinds mechanism belong to the convey mechanism of the active catheter, which can realize the insertion and extraction, rotation, the bending of the catheter tip of the active catheter. The American Corindus company developed CorPath 200 vascular intervention operation robot system. The Imperial College in London and Kagawa University in Japan have also developed a feed mechanism[13,14]. Domestic research is comparatively less, mainly concludesthe catheter / guidewire feed mechanisms developed by Beijing University of Aeronautics & Astronautics University[15] and Harbin Institute of Technology[16]. These institutions are able to achieve the delivery and rotation of the catheter/guidewire, but the functions of disinfection and force feedback are deficient. In view of the specificity of the use of the environment and the use of object, the functions of the mechanism performance and the disinfection cannot be ignored. Therefore, the study still needs to continue.

On the basis of the research above, a new type of tube feeding mechanism is designed, which can imitate hand to twist and pull the catheter/guidewire, and help doctors to finish the intervention of the catheter/ guidewire. The operating device designed is as the main hand, and the tube feeding mechanism is as the secondary hand. The tube feeding mechanism has the func-

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tion of the catheter/guidewire resistance detection, and the driving part and the execution part can be rapidly separated. It can realize the cleaning and disinfection of the executive part. The operating device is used to operate the tube feeding mechanism interventional tube feeding mechanism used in the interventional surgery, and control it to complete the axial movement of the catheter /guidewire along the catheter/guidewire and the circumferential movement around the catheter / guidewire. The operating device includes moving handwheel which can control the movement of the tube feed mechanism and the rotational handwheel which can control the tube feed mechanism to rotate the catheter /guidewire. The operator moves the handle, and the moving hand moves along with the tube feeding mechanism to achieve to push the catheter/guidewire. The operator rotates the handwheel, and the rotational hand rotates along with the tube feeding mechanism to achieve to screw the catheter/guidewire. So, the operation can be done in the manipulating room outside the operation room to avoid radiation in the operation process.

MECHANICAL ARM

Introduction

The mechanical arm is mainly used for the positioning of medical devices in the operation. This paper provides the minimally invasive interventional operation robot positioning system (as shown in Figure 1). The system includes a base, up/down upright column, five-DOF (degree of freedom) humanoid mechanical arm body and six-dimensional force sensor. Five-DOF humanoid mechanical arm comprises a shoulder, upper arm, back-lower arm, front-lower arm. Five rotation joints include the rotation of the shoulder joint, the flexion of the shoulder joint and the elbow joint, the rotation of the front-lower arm, the flexion of the wrist joint. The angles achieved by the rotation of the five joints can realize the positioning for the tube feeding mechanism connecting the mechanical arm end.

Movement analysis of the mechanical arm

Six-dimensional force sensor is fixed at the end of mechanical arm. The each joint coordinate system is built as shown in Figure 2.

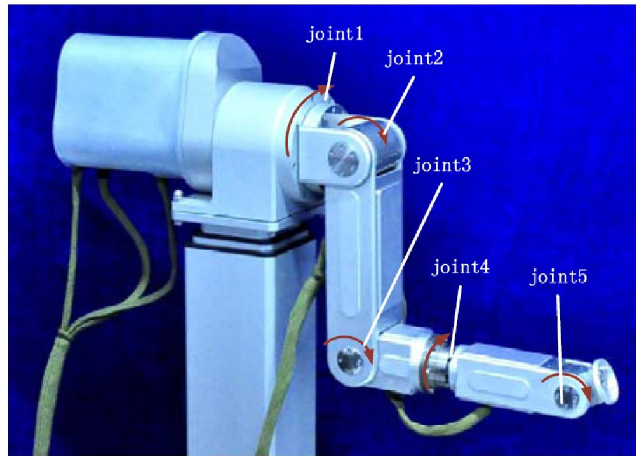

Figure 1 : Prototype of the positioning arm

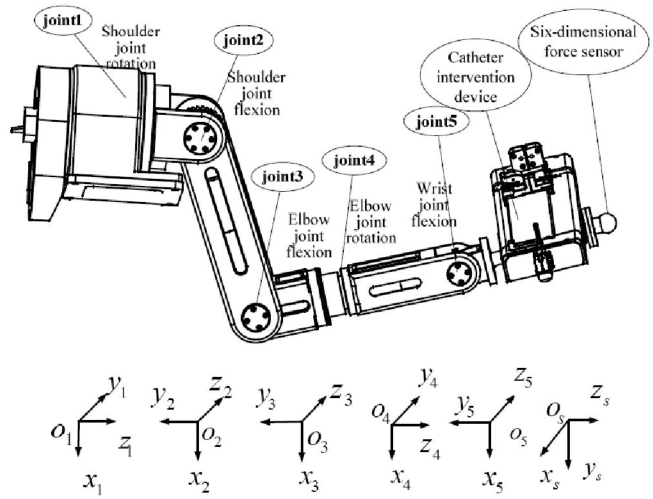

Figure 2 : Joint coordinate system of the arm

The position matrix of the positioning arm is

$$ {}^{0}_{5}T = \prod_{i=1}^{5} {}^{i-1}_{i}T = {}^{0}_{1}T\,{}^{1}_{2}T\,{}^{2}_{3}T\,{}^{3}_{4}T\,{}^{4}_{5}T = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1) $$

SIGNAL TRANSFORMATIONS

In the view of the way of the driving of the mechanical arm, it belongs to the active mechanical arm. This can avoid the problem of the mechanical locking and self-balancing in the design. But if the movement of the mechanical arm is controlled in the way of conventional program control, the demand that the mechanical arm is dragged at any time in the operation can't be meet. Therefore, in order to avoid the predetermined program of the mechanical arm control, this paper proposes a method that the mechanical arm is controlled by the six dimensional force sensor to make the manipulation of the active mechanical arm possess the randomness and flexibility, that is the advantages of both the active and passive mechanical arm are combined to design and manipulate the mechanical arm, which can meet the requirement of minimally invasive operation environment. Six-dimensional force sensor is installed as shown in figure 3.

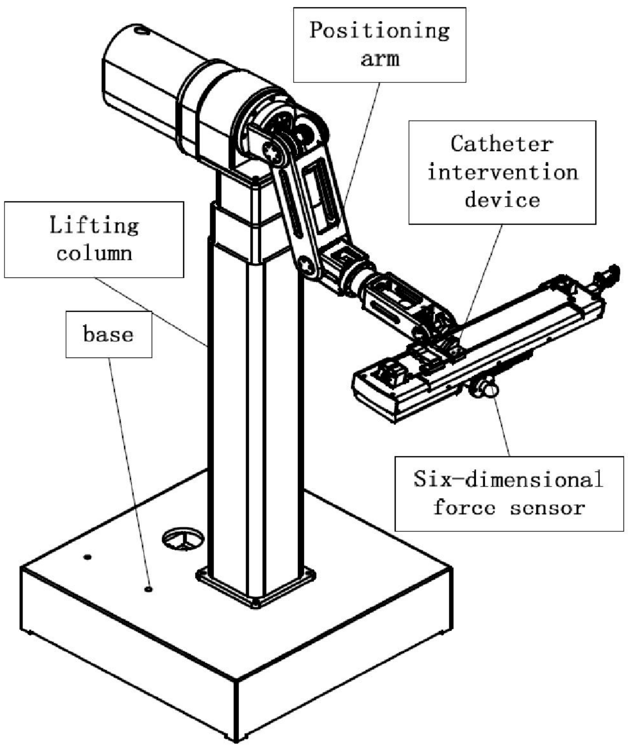

Figure 3 : Six-dimensional force sensor installation

When thesix-dimensional force sensor is dragged, the sensor will output a six dimensional force signal:

$$\mathbf{F} = [\mathbf{F_x F_y F_z M_x M_y M_z}]^T \qquad (2)$$

Based on a transformation, the six-dimensional force signalsare transformed into the position and angle of the mechanical arm end, and then the pose matrix of the mechanical armis shown. After the inverse solution of the mechanical arm, the angles of each joint of the mechanical arm are obtained.

The conversion relation of the above (2) andthe pose vector of the end can be artificially set. In order to make the mechanical arm can be manually dragged along the direction of motion, the three force components should be usedin the same corresponding relationship k_1 to correspond to the three position changes of the mechanical arm;three moment components should be usedin the same corresponding relationship k_2 to correspond to the three pose angle changes of the mechanical arm. So only two conversion coefficients are given, we can obtain the position and angle changes of the mechanical arm, it can be expressed as

$$\mathbf{P} = [\mathbf{k_1F_x\ k_1F_y\ k_1F_z\ k_2M_x\ k_2M_y\ k_2M_z}] \qquad (3)$$

The first three components in the expression correspond to the coordinate system of the mechanical arm end p_x, p_y, p_z in the base coordinate system of the mechanical arm end; The behind three components correspond to α, β, γ in the gesture description method RPY. Therefore,the pose matrix of the mechanical arm end is:

$$T_s = \begin{bmatrix} N_{xs} & O_{xs} & A_{xs} & P_{xs} \\ N_{ys} & O_{ys} & A_{ys} & P_{ys} \\ N_{zs} & O_{zs} & A_{zs} & P_{zs} \\ 0 & 0 & 0 & 1 \end{bmatrix} =$$

$$\begin{bmatrix} c\alpha\, c\beta & c\alpha\, s\beta\, s\gamma - s\alpha\, c\gamma & c\alpha\, s\beta\, c\gamma + s\alpha\, s\gamma & 250 + p_x \\ s\alpha\, c\beta & s\alpha\, s\beta\, s\gamma + c\alpha\, c\gamma & s\alpha\, s\beta\, s\gamma - c\alpha\, s\gamma & p_y \\ -s\beta & c\beta\, s\gamma & c\beta\, c\gamma & 440 + p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

According to the conversion method, it is not difficult to find that the value of the conversion coefficient k_1 and k_2 directly impact the comfort level of operation, and the less the value is, the less the motion amplitude of the mechanical arm under the same force is, that is when the large range of the mechanical arm movement is need, the manipulations need more time and force. But if the value is too large, it means that the less force can cause the large-range movement of the mechanical arm so that it is too sensitive to accurately positioning. Combined with the motion mechanics parameters of human upper limbs and the work space of the positioning mechanical arm, the value of the conversion coefficient k_1 is given. It is set k_1 = 10mm/N · s under the continuous action 1sof 5N the drag force and the movement displacement 50mm of the mechanical arm along the direction of the drag. It is set $k_2 = \frac{10}{3}\pi \text{rad/Nm} \cdot \text{s}$ under the continuous action 1sof the torque 0.05Nm and the rotation angle $\pi / 6$ rad.

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MANIPULATION OF THE MECHANICAL ARM

Transformation of the mechanism and the position matrix

The six dimensional force signals are transformed into the position matrix of the mechanical arm, and according to the different force signals the different pose matrix can be obtained. But due to the mechanical arm with five degrees of freedom, any pose matrix transformed bysix-dimensional force signals cannot be obtained. In order to correspond to the transformed matrix and the pose matrix of the mechanical arm end, a virtual joint is added to the mechanical arm to make it become 6 degrees of freedom. The axis of the rotation joint added is perpendicular to the axis of two joints of the ends, and it is via intersection of the axis of the two joints of the end[17,18]. The way of adding is shown in Figure 4. The joint H is the added joint:

$$\mathbf{T}_{i+1}(\theta_{i+1})\mathbf{T}_h(\theta_h)\mathbf{T}_{i+2}(\theta_{i+2}+\pi)=\mathbf{T}_{i+1}(\theta_{i+1})\mathbf{T}_{i+2}(\theta_{i+2}) \quad (3)$$

Where, $T(\theta)$ is the transformation matrix of the corresponding joint.

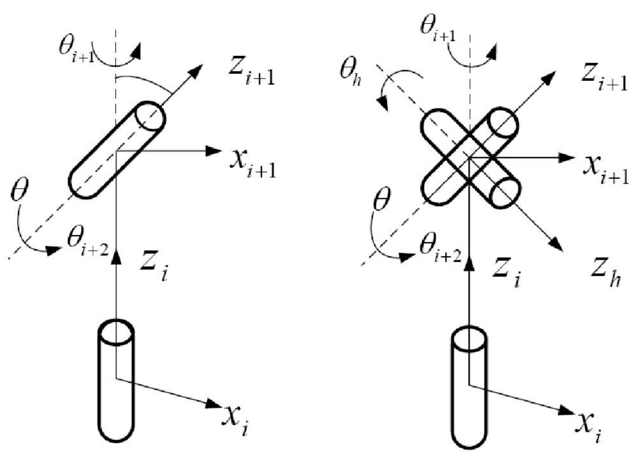

Figure 4 : Method of adding virtual joint

So, the inverse solution problem of the five degrees of freedom mechanical arm is transformed to the inverse solution problem of the six degrees of freedom manipulator. Thepose matrix transformed by the force signals which are outputted by thesix-dimensional force sensor can be the posture of the end of the six degree of freedom mechanical arm. And then theinverse solution of the six degree of freedom mechanical armcan be solved. The variable values of the degree of freedom which are obtained by the inverse kinematics remains constant, that is locking the joint to make it do not rotate, and the other joint variable valuesof the five degrees of freedom is the inverse solution of five degree of freedom mechanical arm.

The mechanical arm has five degrees of freedom, and it lacks a rotational degree of freedom which can regulate the posture. So the mechanical arm cannot reach the all postures which are need above matrix. Therefore, add the lacking rotational degree of freedom, that is add a revolute pairs which is via the intersection of the end two axes andperpendicularto the two axes. Sothe modified mechanism can achieve all postures above. Now the kinematic problems of the modified mechanism are analyzed. The coordinate system of thesix degrees of freedomis set up as shown in figure 5.

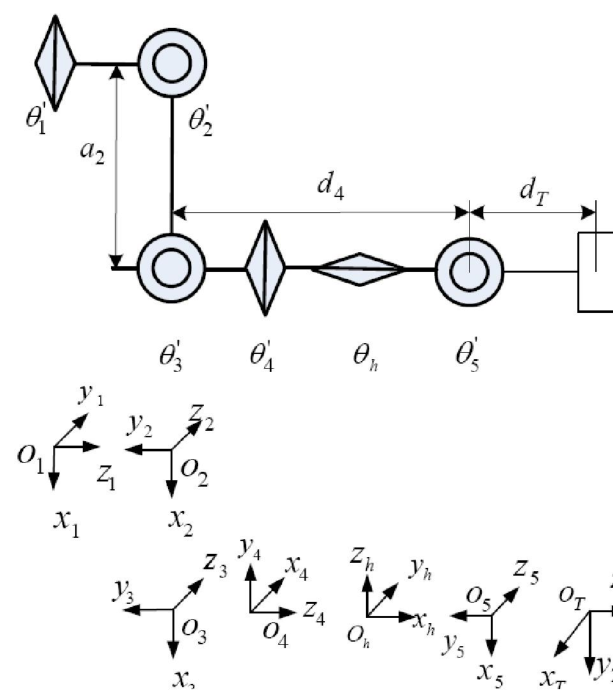

Figure 5 : Coordinate system establishment of the six-DOF mechanism

Coordinate transformation matrixes between every two adjacent joints in first three joints ${}^0_1T', {}^1_2T', {}^2_3T'$ are equals to the first three transformation matrixes. The last three transformation matrixes can be expressed as:

$${}^3_4T'=\begin{bmatrix} c\theta_4' & -s\theta_4' & 0 & 0 \\ 0 & 0 & 1 & d_4 \\ -s\theta_4' & -c\theta_4' & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$ {}^{4}_{h}T=\begin{bmatrix} c\theta_h & -s\theta_h & 0 & 0\\ 0 & 0 & -1 & 0\\ s\theta_h & c\theta_h & 0 & 0\\ 0 & 0 & 0 & 1\end{bmatrix} $$

$$ {}^{h}_{5}T=\begin{bmatrix} c\theta_5' & -s\theta_5' & 0 & 0\\ 0 & 0 & -1 & 0\\ s\theta_5' & c\theta_5' & 0 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}. $$

The result of forward kinematics is

$$ {}^{0}_{6}T=\prod_{i=1}^{4}{}^{i-1}_{i}T\,{}^{4}_{h}T\,{}^{h}_{5}T=\begin{bmatrix} n_x & o_x & a_x & p_x\\ n_y & o_y & a_y & p_y\\ n_z & o_z & a_z & p_z\\ 0 & 0 & 0 & 1\end{bmatrix} \tag{4} $$

Inverse kinematics solution

Set ${}^{0}_{6}T=T_s$, and make corresponding items (3, 3) (3, 4) are equal respectively. The equations (5), (6) can be obtained:

$$ c_{23}c_{h5}-c_4s_{23}s_{h5}=a_z \tag{5} $$

$$ d_6c_{23}c_{h5}-d_6c_4s_{23}s_{h5}+d_4c_{23}-a_2s_2=p_z \tag{6} $$

Let $\left({}^{0}_{1}T^{-1}\right){}^{0}_{6}T=\left({}^{0}_{1}T^{-1}\right)T_s$, and make the items (1, 4) (3, 1) (3,2) are equal respectively. We can know,

$$ d_4s_{23}+d_6c_4c_{23}s_{h5}+d_6s_{23}c_{h5}+a_2c_2=p_x \tag{7} $$

$$ c_{23}s_{h5}+c_4s_{23}c_{h5}=n_z \tag{8} $$

$$ s_4s_{23}=0 \tag{9} $$

Set $\left({}^{1}_{2}T^{-1}\right)\left({}^{0}_{1}T^{-1}\right){}^{0}_{6}T=\left({}^{1}_{2}T^{-1}\right)\left({}^{0}_{1}T^{-1}\right)T_s$, pick up the item (3, 2) in both sides of the equation, and make them equals to each other. Then the equation (10) can be given as

$$ c_4=o_yc_1-o_xs_1 \tag{10} $$

where, c=cos, s=sin, $c_{23}=\cos(\theta_2'+\theta_3')$ $c_{h5}=\cos(\theta_h+\theta_5')$

The inverse kinematics of the six-DOF mechanical arm can be given by solving the equations (5) ~ (10). Then the inverse kinematics of the five-DOF mechanical arm will be worked out. Since the first three joints have no change during the mechanical transformation, the first three joint variables θ_1, θ_2, θ_3 are equal to θ_1', θ_2', θ_3'. In accordance with the transformation expression (3), the following equation (11) can be given.

$$ {}^{3}_{4}T'\left(\theta_4'\right){}^{4}_{h}T'(\theta_h){}^{h}_{5}T'\left(\theta_5'\right)={}^{3}_{4}T(\theta_4)\,{}^{4}_{5}T(\theta_5-\pi) \tag{11} $$

The variables θ_4, θ_5 can be expressed by $\theta_4', \theta_h, \theta_5'$. So, the force signals outputted from the six-dimensional force sensor have been transformed into the joint variable values of the five-DOF mechanism. These joint variable values can be taken as the position control commands to drive the corresponding motors move.

Numerical example

Apply a force of 5N on the six-dimensional force sensor along the horizontal direction in 2 seconds. According to the transforming relationship, a horizontal straight line trace from 440mm to 540mm is our desired trace. During the moving, the end point of the arm is always in the x-z plane in the base coordinate system. It is easy to find that the change of θ_1' will make the end point of the arm leave the x-z plane according to the figure 5. So during the moving, $\theta_1'=0$. Substitute $\theta_1'=0$ into formula (10), we can know that $\theta_4'=0$. Substitute θ_1', θ_4' into formulas (5) ~ (7), we can obtain

$\theta_2'=2\arctan(m)$,

where,

$$ m=\frac{-\left(P_{za}-d_6\right)\pm\sqrt{\left(P_{za}-d_6\right)^2-n^2+P_{xa}^2}}{n+P_{xa}}, $$

$$ n=\frac{P_{xa}^2+\left(P_{za}-d_6\right)^2+a_2^2-d_4^2}{2a_2}; $$

$$ \theta_3'=\arcsin\left(\frac{P_{xa}-a_2c_2}{d_4}\right)-\theta_2', $$

$$ \theta_h+\theta_5'=\pm\arcsin\left(\frac{P_{xa}-a_2c_2}{d_4}\right). $$

Since the joint H is a virtual joint, we lock it and make θ_h=0. We can take $\theta_5'=\pm\arcsin\left(\frac{P_{xa}-a_2c_2}{d_4}\right)$. Substitute θ_5' into formula (11), we can get the expression of θ_4, θ_5.

$\theta_4=-\theta_4'=0$,

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$$\theta_5 = \pi \pm \arcsin(\frac{P_{xa} - a_2 c_2}{d_4}),$$

Thus, the six-dimensional force signals have been transformed into the values of five joint angles.

Sample the sensor force in the horizontal direction once every 0.2 seconds during 2seconds, and the result is given as figure 6.

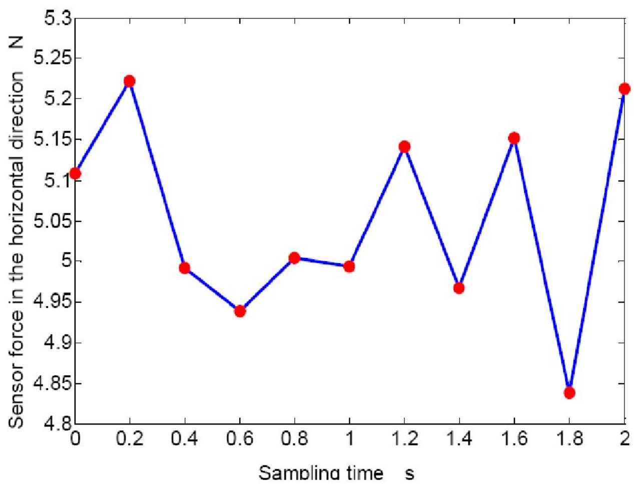

Figure 6 : Output signal of the six-dimensional force sensor

Substitute the values of every sampling point in figure 6 into the above conversion process, connect these points into a line as the track, and do inverse solution for the five-DOF mechanism. Then five joints angle fitting curves can be obtained as figure 7. Take these curves as input to get a trace of the end point, and compare this obtained trace with the desired trace. The trajectory error is shown as figure 8. The maximum error is about 1mm, which fully meets the requirements of the positioning arm.

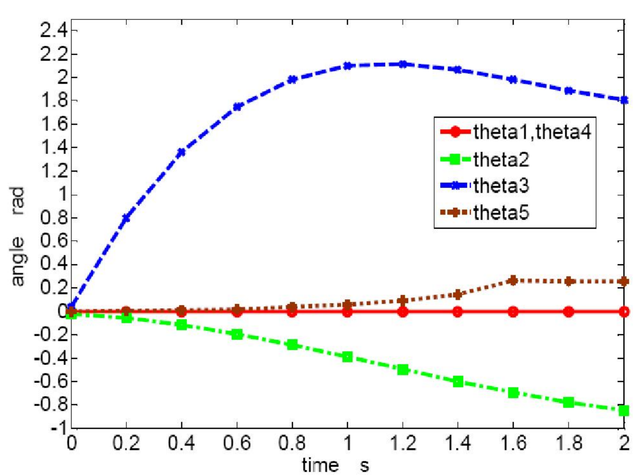

Figure 7 : Joint angle curve

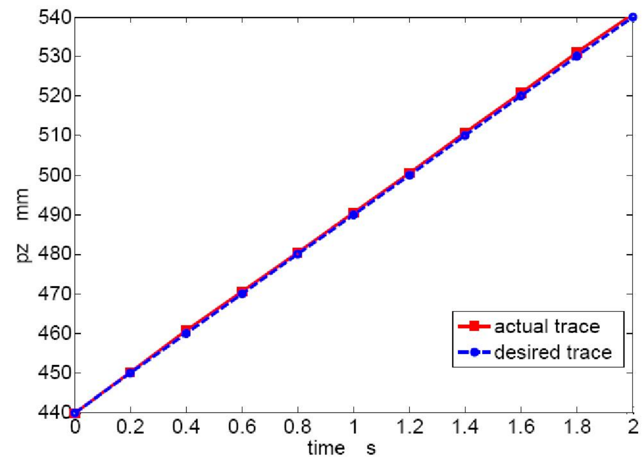

Figure 8 : Trajectory error

CATHETER INTERVENTION DEVICE AND ITS OPERATION METHOD

Intervention device introduction

The designed catheter intervention device includes a catheter fixed finger, a promoting finger and a rotating finger which are shown in figure 9. The catheter fixed finger is used to locate the catheter to pave the way for the guide wire. There are five motors to drive the opening, closing, promoting and rotating of the three fingers respectively. Five motors are arranged side by side as Figure 10 to constitute the device's drive part. The whole drive part can be separated from other components to realize cleaning and disinfecting of the three fingers.

The action of the catheter intervention device is controlled by the manipulation device (shown as figure 11). The manipulation device can achieve two actions: one is promoting the handle, and the other is rotating the hand wheel. These two actions respectively control the promoting and rotating of the intervention device. The operating status of the corresponding actions is given in TABLE 1.

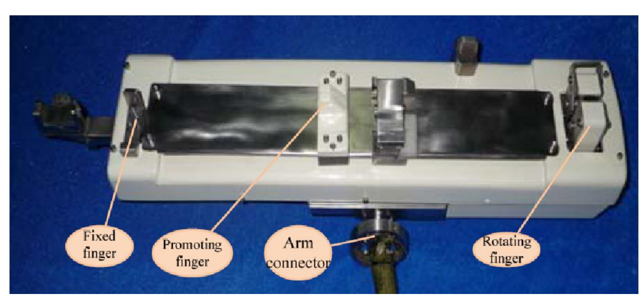

Figure 9 : Catheter intervention device

Figure 10 : Drive part

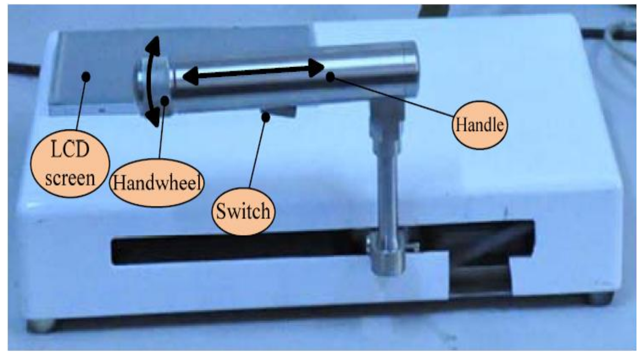

Figure 11 : Manipulation device

TABLE 1 : Operating status of the corresponding action

Operation object	Slave-hand action	Switch	Promoting finger	Rotating finger	Master-hand action
Catheter/ guidewire	promote	on	close	open	Pull the handle to the left
	Empty back	off	open	close	Pull the handle to the right
	Pull back	on	close	open	Pull the handle to the right
	Empty promote	off	open	close	Pull the handle to the left
	rotate	off	open	close	Rotate the handwheel

Master-slave operation

The handle of the manipulation device is connected with a motor through a synchronous belt. An encoder is connected with the motor to record the rotation angle. Take the recorded values as the input signal to the control system. And signalsafter processing can be regarded as the control command to the promoting motor, so the motor drives and the promoting finger begin to move. The distance of the promoting finger move and the handle move have positive correlation. Similarly, the rotation angle of the hand wheel and the rotating finger also has positive correlation. A rotary encoder is fixed in the hand wheel to record the rotation angle. After being processed, the signal can be translate into the control command of the rotating motor in intervention device. A force sensor is fixed in the promoting finger to detect the resistant force when promoting a catheter or a guide wire. This force signal can be processed and feed back to the motor of the manipulation device to drive it rotate and give some corresponding resistance sense to the operator. The control principle of the master-slave operation is shown as figure 12.

(a) Promoting action

As shown in figure 13, the synchronous belt is fixed on the handle through a splint, and moves following the handle. Set P_{zy} as the moving distance of the handle in a single sampling period. R_1 is the radius of the belt wheel. n_{zy} is the pulses number of the encoder record. The reduction ratio of the transmission is i_y. The relationship among these parameters can be expressed as follows:

$$n_{zy} = \frac{r_y i_y}{\pi R_1} P_{zy},$$

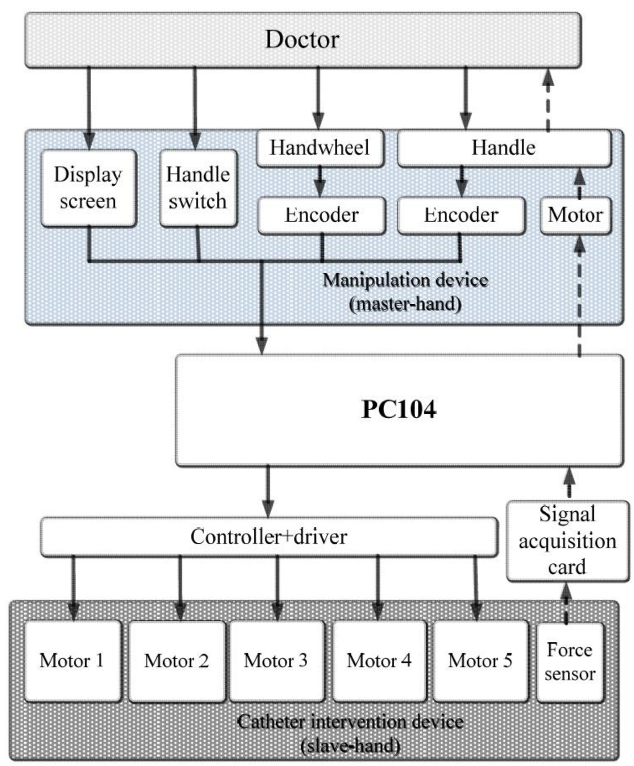

Figure 12 : Control principle of the master-slave operation

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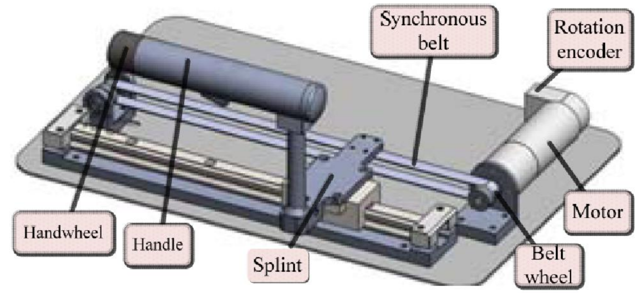

Figure 13 : Internal transmission structure of the manipulation device

The pulses number of the encoder record n_{zy} multiplied by a scaling factor k_y can be acted as a position control command to drive the promoting motor rotate. The promoting distance of the promoting finger in a single sampling period can be obtained.

$$P_{cy} = \frac{k_y n_{zy}}{4 r_g i_g} S,$$

where, r_g is the resolution of the encoder which is connected with the promoting motor of the intervention device. i_g is the reduction ratio, S is the screw lead. By changing k_y to change the corresponding relationship between the distancesthat the master hand moved and the slave hand moved. Then the fast promoting, slow promoting and fine tuning can be realized. Conversion between the various file can be achieved by manipulating the control buttons on the LCD screen.

(b) Rotation action

When the operator rotate the hand wheel, the rotatory angle can be set as θ_{zz}, the outputted pulses number of the rotary encoder fixed in the hand wheel is n_{zz}, and the resolution of the encoder is r_z. An equation can be given.

$$n_{zz} = \frac{2r_z}{\pi}\theta_{zz},$$

The corresponding rotary angle of the catheter or the guide wire can be expressed as:

$$\theta_{cz} = \frac{k_z n_{zz}}{4 r_z i_r} \cdot \frac{r_2}{r},$$

where, i_r is the reduction ratio of the rotating finger, r_2 is the radius of the active belt wheel, r is the radius of the catheter or the guide wire. n_{cz} is the pulses number of the rotary encoder connected to the rotating motor. By changing the value of the proportionality coefficient k_z, the relationship of the two angles can be changed to realize multi-gear control. Conversion between the various file can also be achieved by manipulating the control buttons on the LCD screen.

CONCLUSIONS

A minimally invasive cardiovascular intervention surgery robot system is introduced. The paper presents every components of the system and gives their operation mode.

(1) Combined with the characters of the active and passive mechanical arms, a novel operation mode is proposed to realize freely operation. By working on a six-dimensional force sensor which is fixed on the end of the arm, the six-dimensional force signal can be record and translated into a posture matrix as the end position of the arm.

(2) To correspond with the posture matrix, themechanical arm should be changed into a six-DOF mechanism complying with some rules. Take the posture matrix as the end position of the six-DOF mechanism, and do inverse kinematics to obtain every joint rotation angle. Then the inverse kinematics of the five-DOF mechanism can be obtained. A specific sample is given to verify the feasibility of this method. This operation mode can make the arm's operation freely and arbitrarily without predetermined program.

(3) A master-slave operation mode between the catheter intervention device and its manipulation device is given. The paper mainly gives the mapping relationship of the promoting and rotating motions between master and slave hands. This way of operation can protect doctors from radiation.

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