

Elbow driver installation structure optimization design for robotic artificial limbs

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Abstract: Robot artificial limbs has six degrees of freedom. elbow tilting mechanism is driven by a through type linear motor. To determine the elbow installation structure of driven by linear motor, this paper uses the optimization design method, to determine the structure design of the optimization variables, the structure of the motion mathematical model is established, design constraints and objective function is constructed, the comprehensive optimal solutions is gotten by the optimization-algorithm of compound form. Finally, the optimization results is exported and the kinematic simulation graphics is drawn. Considers various factors, From the motor installation space, motor drive efficiency, forelimbs movement range to driving moment, obtains the optimal solution and proves the rationality of the design.

Introduction

According to a second national survey of disabled persons and a notice issued by the national bureau of statistics in 2006, there are about 24.12 million dismembered patients in China currently, twenty-nine percent were patients with upper limb disability. Now, every year, tens of thousands of healthy people are dismembered by natural disasters, diseases, wars, traffic accidents and other causes. The wenchuan earthquake in May 2008 and the yushu earthquake in April 2010 brought physical disability to nearly 30,000 people. There is a need for limb function and beauty in the mutilation patients, wearing prosthesis is the main means to realize its demand. As a result, the design and development of artificial limbs is related to the happy life of many disabled patients and also has great market potential.

The robot prosthesis in this paper contains six degrees of freedom. This paper mainly introduces the problem of elbow joint drive mounting structure. Elbow tilting mechanism adopts a through type linear motor drive, 135 ° forearm swing can be realized. In order to ensure that the motion of the elbow mechanism can work effectively in linear motor make the swing range of elbow joint can reach 135 °. In order to fully consider the requirements of installation space, not self-locking, no motion interference, etc., it is difficult to accomplish this task with the traditional design method. On the basis of detailed analysis of various components and movements of the institution, In this paper, by means of optimization design, a mathematical model of optimum design is established, and the synthesis optimal solution of each component of the elbow joint

swing mechanism is obtained by using the compound algorithm. In order to verify the correctness of the optimized design results, a motion simulation was carried out on the swing process of the mechanism while optimizing the design. The above work is done in the MATLAB software environment.

3 D model of Robot prosthesis

3d modeling is based on the following design method, according to the 2d drawings, the components are first modeled and then assembled. In the process of modeling and assembly, many design problems (such as limitation, interference, etc.) were found, and the two dimensional drawings were modified to model again. After many modifications, the final elbow joint and the total assembly three-dimensional schematic diagram are shown in figure 1 and figure 2.

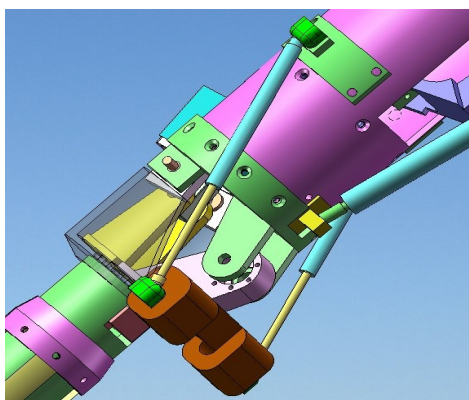


Figure 1 The assembly drawing of elbow structure

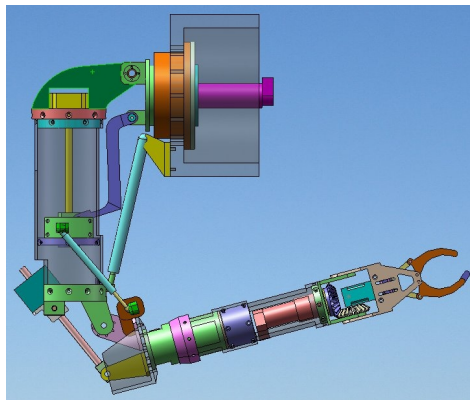


Figure 2 General assembly drawing

Determine the elbow joint structure

As shown in figure 3, the one that connects to the hand we call the forelimb, In the design of the robot's forelimb structure, the straight line motor with spiral auxiliary output linear motion is driven by the forelimb. The connected linear motor is mounted on the big arm, when the linear motor is driven, the screw of one of the screws is driven by the motor to do the linear expansion motion, and then the rotation of the elbow joint is promoted.

The schematic diagram of the implementation of the mechanism is shown in figure 1. Figure 3. a is the initial state of the forelimb, and figure 3. b is a movement state of the forelimb.

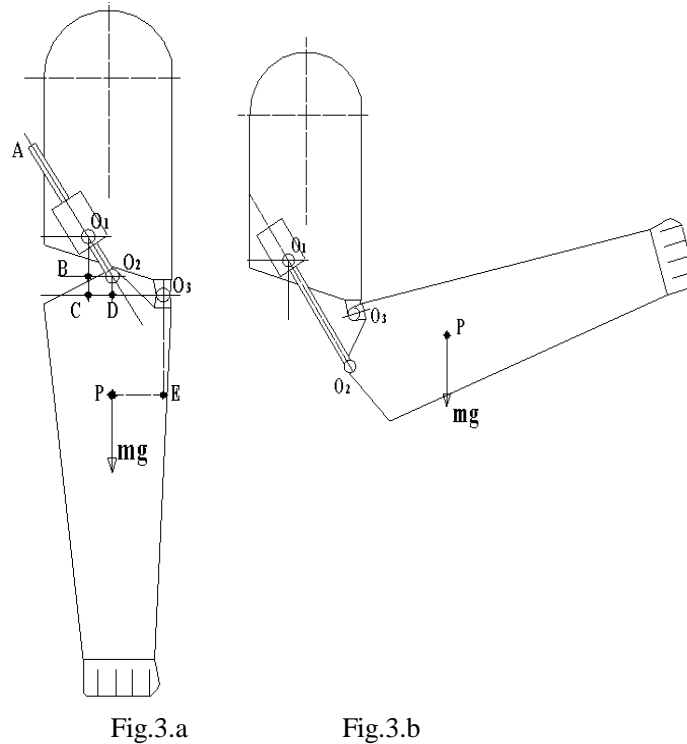


Fig.3.a Fig.3.b
Fig.3 Schematic diagram of the elbow swing

Determine the structure design of the optimization variables

When the forelimbs are beginning to droop, the distance from the point O3 to the rotation point O1 of the big arm linear motor, as a design variable, the name is x1;

When the forelimbs are beginning to droop, FIG. 3a shows the length of BC, as a design variable, named x2;

When the forelimbs are beginning to droop, FIG. 3a shows the CO3 horizontal length, as a design variable, named x3;

When the forelimbs are beginning to droop, figure 3a shows the horizontal length of DO3, as a design variable, named x4;

When the forelimbs are beginning to droop, the center of gravity of the forelimb deviates from the elbow joint point O3 in the horizontal direction to the EP, which is a fixed value; The distance from the elbow joint point O3 is the O3E length, which is a fixed value in the high direction.

The optimal design procedure of the elbow joint drive installation is prepared by MATLAB, which mainly includes the following program contents:

The design variables of x1, x2, x3 and x4 are designed to limit their range of values and initialize them.

The structure of the motion mathematical model is set up

In the range of the forelimb movement, the mathematical model of the motion parameters of heavy torque M and driving moment M are established.

$$f_0 = \arctg\left(\frac{EP}{EO_3}\right)$$

$$f = \Delta f - f_0$$

$$a' = \sqrt{(x_3 - x_4)^2 + (x_1 - x_2)^2}$$

$$b = \sqrt{x_1^2 + x_3^2}$$

$$c = \sqrt{x_2^2 + x_4^2}$$

$$a_0 = \arccos\left(\frac{b^2 + c^2 - a'^2}{2bc}\right)$$

$$a = \sqrt{b^2 + c^2 - 2 \cdot b \cdot c \cdot \cos a}$$

$$p = (a+b+c)/2$$

$$L_1 = \frac{2 \cdot \sqrt{p(p-a)(p-b)(p-c)}}{a}$$

$$L_2 = \sin f \cdot \sqrt{EO_3^2 + EP^2}$$

$$M_{\text{动}} = F \cdot L_1$$

$$M_{\text{重}} = m \cdot g \cdot L_2$$

Where $\Delta\phi$ is the independent variable, which is incremental numerical forelimbs movement, value range is $0^\circ - 135^\circ$

ϕ is the Angle between PO3 line and O3 point perpendicular, When the value is negative, the Angle is on the left of the perpendicular line, while the value is positive, the Angle of the Angle is on the right side of the vertical line, and it is the variable.

$c = O_2O_3$, Constant value

$b = O_1O_3$, Constant value

$a = O_1O_2$, Variable, is equal to the motor screw length

$\alpha = \alpha_0 + \Delta\phi = \angle O_1O_3O_2$, Variable

L_1 . Power arm

L_2 . Heavy arm

F -The motor rated thrust

M -the forelimb weight, center of gravity on the point P

G - gravity acceleration

Building structure design constraints and objective function

According to the installation space of the linear motor, the installation space of each connecting rod, the motor drive efficiency, the range of motion of the forelimb, the motion interference can't occur, etc, to design constraints for each design variable, for example, the implementation example USES the following constraints:

$$G_1 = 10 - x_1 \leq 0$$

$$\begin{aligned}G_2 &= x_1 - 55 \leq 0 \\G_3 &= 10 - x_2 \leq 0 \\G_4 &= x_2 - 40 \leq 0 \\G_5 &= 40 - x_3 \leq 0 \\G_6 &= x_3 - 120 \leq 0 \\G_7 &= 40 - x_4 \leq 0 \\G_8 &= x_4 - x_3 \leq 0 \\G_9 &= 20^\circ - \alpha_0 \leq 0 \\G_{10} &= \alpha_0 - 50^\circ \leq 0\end{aligned}$$

The maximum absolute value of the driving moment generated by the linear motor driving force on the range of the forelimb is the target function:

$$\begin{aligned}\Delta M_i &= \text{abs} (M_{\text{dynamic}i} - M_{\text{heavy}i}) \\f(x) &= \max(\Delta M_i)\end{aligned}$$

Among them: $M_{\text{dynamic}i}$ indicates that the driving torque generated by the driving force of a linear motor during the movement of the elbow is in a different position in the forelimb, and $i = 1 \dots N$;

$M_{\text{heavy}i}$ indicates that the weight of the front limb of the elbow during the movement is in different positions in the forelimb, and $i = 1 \dots N$;

ΔM_i said elbow in the process of motion driving moment and forelimb weight torque in the fore in a different position when the absolute value of the difference between the, $i = 1 \dots N$, In this case, the general drive moment is less than the forelimb, and the residual torque can be solved by some kind of balancing device.

$F(x)$ is the maximum in ΔM_i , is the objective function, the result of optimization design is to achieve minimum $f(x)$, The maximum value of the driving moment and the weight of the forelimb is minimized in the condition and activity range of the forelimb.

The integrated optimal solution

When the linear motor drive range is 0-135mm, the maximum driving force of the motor is 80N. The movement range of the forelimb is greater than 0 -- 135, with the forelimb weighing 5Kg. At the initial position, the center of gravity of the forelimb is in the forelimb, the vertical distance of the elbow joint is 200 mm, and the horizontal distance is 40mm. Running MATLAB optimized program, the optimization design of the elbow joint drive structure was carried out with the compound optimization algorithm. The main optimization results were:

$$\begin{aligned}x_1 &= 24.1773 \text{ mm} \\x_2 &= 17.7877 \text{ mm} \\x_3 &= 72.3559 \text{ mm} \\x_4 &= 70.4325 \text{ mm} \\ \text{The objective function } f(x) &= 6.897 \text{ Nm}\end{aligned}$$

Motion simulation results

To verify the correctness of optimization results, at the same time, a motion simulation program was developed with MATLAB. The optimal design result can be output directly by the simulation graph, figure 4 is the simulation of the design results, the drive simulation and motion curve of the elbow joint in motion are shown.

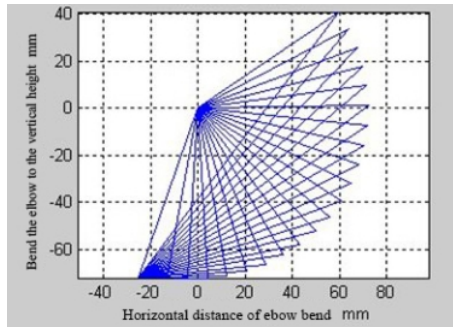


Fig 4(a) The elbow flexion and process

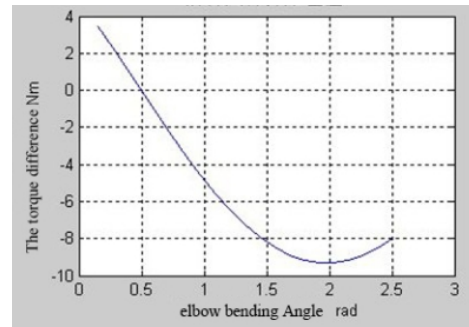


Fig 4(b) Torque difference elbow flexion and extension

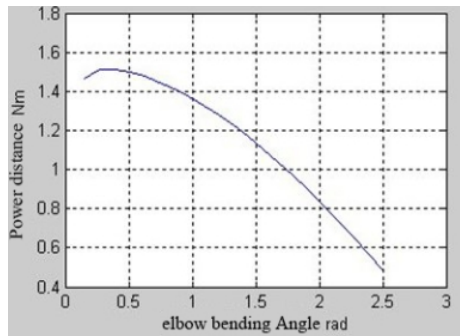


Fig 4(c) Power from the elbow flexion and extension

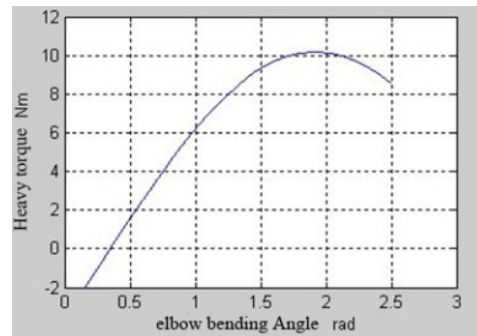


Fig 4(d) The gravity from elbow flexion and extension

Fig 4 Driving simulation and motion curve of elbow joints in the motion process

Conclusion

Using MATLAB as the platform, using the compound algorithm in optimization design theory, the optimal design of the arm swing mechanism of the prosthesis was carried out. The optimal design parameters are obtained. The correctness of each parameter is verified by the motion simulation of computer graphics and data. Design results show that the optimization result of the swing mechanism of elbow is consistent with the design requirements of compact space, non-interference and light weight, etc. The practical application of prosthesis provides strong technical support.

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