Mechanics-homogenization Algorithm and Optimization Design of the Flexible Manipulator Based on the Bionics

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ABSTRACT

Based on the bionics, in the light of human hand, a flexible manipulator is created with two parts: the thumb part and the four finger part. The compound-eye technique is adopted to set up multiple regions, and each region has a number of minute palm slices for control of the object to grasp and hold through the distribution of "quincuncial piles" of these slices. According to the object geometric shape feature and combination of the minute palm slices, such manipulator through the simulation is constructed by determination of the regional average pressure on all the minute palm slices, and by adjustment of working face with the pressure-homogenization method. Under control of PLC, the justification of the minute palm slices is done with different working heights for various geometric parameters of different objects, to ensure that each minute palm slice is with uniform load, high efficiency, guaranteeing the reliable grab and hold, uniform wear of the working face, and long service life.¹

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Manipulator, Minute Palm Slice, Homogenization Algorithm, Difference Method, Plum Pile Layout

INTRODUCTION

Robot arm and hand are the execution parts of robot system, which can embody the function of robot. Usually, the robot manipulator hand, adopts the fixed structure form, to adapt the specific piece of capture, and complete the follow-up operation. In order to make the robot adapt to the grasp of a variety of objects with different shapes, on the one hand, improvement of the intelligent control is done, on the other, the function of the arm palm is further to be developed. Maric, Filip et al. [1] in order to realize compatible type of flexible robots, explored and built a simple and intuitive remote control with three degrees of freedom of a robot arm, using color and depth image camera to obtain the position of the palm of user, and then determine the robot arm position. Ogasawara, Keisuke et al. [2] described the incorporation of the palm of the robot arm that was designed to accommodate the needs of the different forms, and expected to set up the incorporation within the thumb and minute fingers. Newby, Brad et al. [3] designed and controlled prosthetic hands with flexibly rotating palms, by increasing degrees of freedom to adapt to different objects. Choudhary, Ganesh B. Et al. [4] proposed a pure electronic man-machine interface without any mechanical sensing. His manipulator was more intuitive, and discarded the traditional handle and button. Cerruti, Giulio et al. [5] designed a humanoid robot with the compact and lightweight machine hand through precise finger gestures and the sensing force feedback signal for realization of the machine hand posture and adaptive action. Asheber, W.T. et al. [6] studied the palm of the multi-function robot, which effectively grabbed and controlled the objects through visual and tactile sensing, thus simplifying the grasping and control mechanism. Emmanouil, Evangelos et al. [7] proposed a spherical triangular form of spherical palm-palm-joint angular calculation, and the spherical palm was composed of several spherical triangular pieces, forming decomposing and composite palmate-shape. Tian, Mengqian et al. [8] developed the human hand of the pneumatic flexible machine that simulated human hand shape and posture. It consisted of fingers and palm, with two joints in the thumb and three joints in four fingers. Flexible drives made from good scalability and elastomers are used to drive finger movements. Muhlbacher - Karrer, Stephan [9] put forward a kind of based on iterative Bayes algorithm, a new method of fetching content classification including humanoid hand, using the new capacitance sensor for detection of internal properties. Mughal, Asif Mahmood [10] constructed a humanoid hand model by using the Simmechanics Analysis, and it had four fingers and a thumb, linked together hand humanoid hand equipped with mini servo motor and gear mechanism. Lin, yu-chi et al. [11] explore the robot navigation planning framework of humanoid
robot, which comprehensively USES the palm foot contact to realize the navigation of the unknown complex environment. Yabuki, Yoshiko et al. [12] developed a new space for flesh potential prosthetic hand gloves, suitable for people true form and flexible hand movements. The point of the glove is with fetching function, shape, durability, and flexibility, including wrinkles, finger prints, nails and skin tones.

So far these kinds of palm structure forms are to be consistent with the grasping surface of specific parts, which is a kind of stationary relative ideal combination. However, the problem the combination is that when the geometric parts, especially when fetching face shapes, changed, the robot manipulator/palm cannot change according to such parts. Therefore, it is not the ideal combination. The current study aims at creating a flexible palm of the robot manipulator through statistics of certain number of objects and with the similarity principle of group technology, to design a "compound palm" composed of series of "minute palm slices", for flexible combination to adapt different shape parts.

**PHYSICAL FEATURE AND ADAPTIVE ANALYSIS OF HUMAN HANDS**

When people hold an object, the procedure of it is open the hand, move the hand in such a position that the object is just in the hand, close the hand with the thumb and four fingers in tuck, and eventually grasp the object firmly. From the physical sense, the grip is the evolutionary process of the relative position, relative velocity and deformation of the hand.

Look from the mechanical process, holding comments no contact between the hand and object - no action, through local contact - had an effect, enlarge the contact area pressure, terminate hand face all - reach maximum pressure and keeping contact with the object.

From adaptive biological process, it is the thumb, four fingers, palms, and the skin receptors (including hair and skin) in caught under the action, feel the distance, texture, temperature, pressure, and other information and transmit the information to the brain nerve center through the nervous system (system control center), and then the nerve centre after combining and processing information forms a decision and feedbacks to the nervous system to control the further movement of the hands (especially the area of low pressure further hold). When an object has a downward trend, the thumb, palm and four fingers are further closed and closed. On the contrary, when the object has no downtrend, the hand parts remain in position.

If a fetched object is in horizon with some geometric elements for support, this situation is out of question and may not be discussed here.
IDEAL GRASP AND FORCE REQUIREMENTS OF THE HAND

The "grasp" of the object is the "positioning" and "clamping" of the space position under the action of the manipulator, so that the object can't move at the specified space.

In contrast to the positioning of mechanical manufacturing technology, the degree of freedom of the vertical direction is assumed to be assumed by the manipulator when the manipulator holds the object. The detailed analysis is as follows.

The simulation of human hands mainly carries on the biological abstraction and mechanical abstraction to achieve the purpose of "grasping".

Based on the most commonly used cylindrical surfaces, a number of regions are divided. Each area is subdivided into multiple minute palm, pressure sensor mounted on the minute palm to grasp force confirmed by simulation and experiment, obtain the actual form of adaptive layout and grip size.

Mimics, and hand thumb has closed to grasp of the object, the present invention will hand grasp the abstract into two cylinders fold, among them, the part of the thumb is relatively fixed, palm and four fingers (hereinafter referred to as the palm) for thumb relative to another part of the rotary closed exercise; The back of the hand is the cylinder, the palm of the palm is the positive prism.

Each plane in the prism is a region, and each region has a number of minute pallet pieces, as shown in figure 1.

The compressive limit of the object is set according to the object characteristics and geometric appearance of the seized parts. The size of the control force is calculated according to the weight of the control piece:

\[
\begin{align*}
\sigma &= \sigma_{\text{lim}} \\
P\mu &= w \\
P_w &= k \frac{w}{\mu}
\end{align*}
\]

Where, the compressive limit of the object to be grasped; \( P \) is radial force; \( \mu \) is the friction coefficient between the object and the minute pallet; \( W \) is the weight of the handle; \( P_w \) is the practical control force; \( k \) is the adjustment coefficient.

Calculate the basic control force, multiplied by the adjustment coefficient, obtain the practical control force, ensure reliable control of the object without damaging the surface of the object. In order to calculate the installation number of minute pallet, let the control force of each minute slice is \( P_i \), then

\[
n = \frac{P_w}{P_i} = \frac{k \frac{w}{\mu} \Delta S \sigma_w}{\mu \Delta S \sigma_w} = \frac{k w}{\mu^2 \Delta S \sigma_w}
\]
Where $\Delta S$ is the average working area of the minute palm.

THE DIFFERENCE ALGORITHM OF PRESSURE HOMOGENIZATION

Divide the effective palm into a number of regions, each region according to "plum pile" setting minute palm slices. Five regions are employed numbered 1,2,3,4,and 5 respectively for the thumb region, the stationary part of the palm., the finger region a , finger region b, finger region c, and finger region d. These five regions are distributed on the cylindrical surface and form three-dimensional space. Further, finger region a and finger region b form a large sector, sector B, so are finger region c and finger region d for sector C. If thumb region is taken as sector A, then the three sectors form a triangle in space firmly.

Determination of the average working pressure in each sector and the pressure range on the slices. Let $P_a(x,y,z)$ be the ideal average pressure on the sector, and $P_{ai}(x,y,z)$ ($i=1,2,3$), then the relative error between real average pressure and the ideal average pressure is

$$D = \left( \frac{P_{ai}-P_a}{P_a} \right)$$

In a sector $i$, select a slice $j$ randomly, upper which the instant pressure is $P_{ij}$. Then the relative error between real instant pressure and the ideal pressure is

$$D_{ij} = \left( \frac{P_{ij}-P_{ia}}{P_{ia}} \right)$$

Take the difference number

$$\Delta D = D - D_{ij}$$

When $\Delta D$ is greater than $D_{ij}$, make the pieces closer to and grip the object; when $\Delta D$ is less than $D_{ij}$, loose the slice; and make the slice firm and fixed when $\Delta D$ is equal to $D_{ij}$.

OPTIMIZATION LAYOUT AND DESIGN OF STRESS POINTS

Press "plum pile" on the base of thumb and palm to install the minute slices and make coarse adjustment. Simulation method is used to test the actual pressure of each slice. If the work pressure is too minute, adjust the minute hand piece, make it go further to tighten the control piece; if the work pressure is too big, adjust minute slice into the palm or thumb, according to the following criterion.

When the requirement is met, then lock the minute slices:

$$|P_i - P_w| \leq \varepsilon$$
INTELLIGENT CONTROL PLAN

The control of manipulator is essentially the control of the state of the hand. The mechanical hand state can be expressed by the vector $J$:

$$J = \{ j_1, j_2, \ldots, j_m \}$$

Where $j_k$ represents the state in which the manipulator corresponds to the k-th action during the logical movement; $P_o$ is a set pressure, the measured pressure $P$ on the palm, and the deviation from the setting pressure $P_o$ is the $\Delta P$, i.e.

$$|P - P_o| \leq \frac{1}{2} \Delta P$$

The specific logical action process is controlled as follows:

Action 1: Open the hand, ready to stretch out
At this time, the robot can set the space state of a certain distance between the manipulator and the object to hold so that the arm can drive the movement of the hand and the adjustment of the object plate.

Action 2: Forward the arm and close to the object
The palm with the arm together approaches the object in the proper direction.

Action 3: Detect the object and place in palm
According to the object characteristics and scraping parts of the geometric elements referring to the movement of the ideal position in the whole palm, the distance is calculated between the object and a corresponding minute slice for
preparation of a rapid and reliable grasp of the object. The space relationship between the object and palm is shown in Figure 3.

Action 4: Close palms, contact object

In this state, the palm finger is driven by the stepping motor, with a certain angular velocity to the thumb, and contact the object first with a minute slice of the palm

![Figure 3. The logical actions of the palm.](image)

Action 5: Pressure –regulate and achieve uniform pressure
Action 6: Full grasp and complete hold

In the process of the pressure test and the adjustment of the minute slices, the single step motor can be used for the parallel operation, which can be fast and reliable. See Figure 3 for the above logical actions.

CONCLUSIONS

The palm of this manipulator is based on the principle of bionics, and it is divided into the thumb part and the four finger part. In order to simplify the structure and make it more practical, the thumb part is tentatively fixed and abstracted and enlarged into some sleeve body, its basic working face is some kind of cylinder. To combine the four fingers with the palm and abstract them into a movable part of the sleeve, the basic working face of it is also partially cylindrical.

The "compound eye technique" is used to set up multiple regions, and each region has a number of minute palm slices, which can be used to control the object through the distribution of plum piles. According to the object geometric shape features selection and combination of the minute slices have been done. Through simulation the determination of the regional average pressure and the fundamental minute slice pressure is realized for adjustment of the distance between the working face and the slices.

By using the principle of the pressure homogenization of intelligent control, through the overall control of PLC, respectively to adjust minute palm components working height of the actual size, forming a flexible palm with pressure uniformity to adapt various geometry parts of the object.
In relatively microscopic view, the minute slices are scattered on the inner surfaces of the thumb and the fingers according to m "quincuncial piles". Under the reliability of grasp, it is better to have the number of minute slices as less as possible. Each minute slice is independently adjustable, thus ensuring the minute palm slices with uniform load, for the high efficiency, reliability, uniformly face wear, and long service life.

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