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Design and development an insect-inspired humanoid gripper that is structurally sound, yet very flexible

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Abstract. One of the biggest challenges in mechanical robotics design is the balance between structural integrity and flexibility. An industrial robotic gripper could be technically advanced, however it contains only 1 Degree of Freedom (DOF). If one is to add more DOFs the design would become complex. On the other hand, the human wrist and fingers contain 23 DOFs, and is very lightweight and highly flexible. Robotics are becoming more and more part of our social life, they are more and more being incorporated in social, medical, and personal application. Therefore, for such robots to be effective, they need to mimic human performance, both in performance as well as in mechanical design. In this work, a Humanoid Gripper is designed and built to mimic a simplified version of a human wrist and fingers. This is attempted by mimicking insect and human designs of grippes. The main challenge was to insure that the gripper is structurally sound, but at the same time flexible and lightweight. A combination of light weight material and a unique design of finger actuators were applied. The gripper is controlled by a PARALLAX servo controller 28823 (PSCI), which mounted on the assembly itself. At the end, a 6 DOF humanoid gripper made of lightweight material, similar in size to the human arm, and is able to carry a weight of 1 Kg has been designed and built.

1. Introduction

When it comes to the mechanical design of robotic grippers, designers are faced with the following dilemma; make the gripper very flexible, while keeping it light weight and structurally sound. The problem is that these two requirements are just the opposite of each other.

To make the robot more flexible, one needs to add more DOFs, which means more actuators, connectors, cables, housing, etc. which will the gripper heavier and more complicated. That is why most industrial grippers have limited number of DOFs [1]

However, when one observes the human hand, one can see not only is it highly flexible (23 DOFs for the wrists and fingers of one hand), but it is also light weight, especially when it is compared to the weight of industrial grippers. The same can be observed in insects' legs and other extremities. Each leg is very light and yet very complex. [1, 2]

Therefore, this work attempts to build a gripper that is closer to the human form, as much as possible by trying to mimic human and insect form.

2. Literature Review

Attempting to achieve flexibility and structural integrity is not new. There were differences in methods and technologies, each with its advantages. (So and so) combined the use of ultrasonic motors and elastic elements. In this design, the gripper size the same as the human hand, it has almost the same number of DOFs of the human hand [2,3].

The motion is achieved the ultrasonic motor and the elastic elements in it. The ultrasonic motor is powered by ultrasonic vibration of the stator against the rotor, which allows this motor to achieve a large rotation angle. The advantage of the ultrasonic motor is its compact size and high torque that allows it be mounted on the linkage and be used to drive the robot's fingers. This allows the gripper to be reduced in size and dimensions [4].

Another technique builds the gripper out of elastic material and is powered by compressed air. This was developed by Virginia Tech's Robotics and Mechanisms Laboratory of the College of Engineering. It uses microcontroller commands to control the movement on the fingers. This robot hand is mainly operated by using the compressed air.

The material of the robot hand is mainly elastic ligaments. The fingers will hold tight together when the air inside the fingers is being compressed. This robot hand has 1 degree of freedom on each finger. The pressure of the air can be adjusted to manipulate different object, lower pressure is required when the robot hand is holding a soft fragile object while high pressure is used to hold an object tightly [5].

R. D. Howe, et. al discovered that a cockroach leg is very flexible and acts like a spring., which allows the cockroach to walk or run on uneven surface. The robot fingers are made by using plastic springs that could deflect naturally and so are flexible to grasp a wide range of objects. Besides, the material is light in weight and cheap. The main components that operate inside the hand are cables and pulleys which run by motors. [6]

3. Design and Methodology

The design of this gripper is divided into three main categories, 1) design of the fingers, 2) design of the palm, 3) the design of the actuators, and, 4) programming the motion of the gripper.

3.1. Design of the fingers.

The fingers were made of a rubber tubing that has been cut off in strategic places, then a nylon line was fixed to the tip of the finger, and the other end to be connected to the servo motors.

Figure 1. The Design of the fingers used in this project

As it can be seen, the design is very elastic, light weight, yet structurally sounds. The range of its motion can be easily modified by redesigning the locations of the cuts in the rubber tube. Three basic cuts were made to create the three knuckles.

3.2. Design of the Palm, and mounting of the Actuators.
The rubber tubing was then mounted on wooden rods, which in turn were mounted on the palm. Next the whole assembly is mounted on the arm, where the servo motors, controller, and power source were mounted.

This Arrangement greatly mimics the design of the human arm, where the muscles powering our fingers are actually "stored" in the forearms. When you flex your fingers you will notice your muscles at the forearms contract and expand in correspondence to your fingers.

Figure 2. The Complete design of the humanoid gripper

3.3. Controlling the motion of the gripper.
To control the motion of the gripper, the PARALLAX 16 channel servo controller is used. This servo controller uses USB port to communicate with the controlling intelligence. It allows 16 channels of servo controlling by sending commands from a microcontroller via PC or USB connection.

Figure 3. Mounting of the controller unit in the forearm of the gripper.

Since this work focuses on the mechanical aspects of the design, little effort was directed towards programming of motion. Therefore, the method of teaching was utilized. The PARALLAX 16 channel servo controller comes with its own software package, named PSCI.

This software allows the user to control the motion of each motor of the assembly, i.e the motion of each finger. A complex motion can then be created by creating the motion of each finger separately, saving it, and then playing it together at once.

4. Results and Findings

The original objective of this work is to build a light weight, structurally sound robotic gripper that is inspired by human and insect designs.

To demonstrate the flexibility and agility of this gripper, it was programmed to grip several objects and perform several hand gestures, such as "Fist, Rock, Pointing" and others.

4.1. Gripping several objects
As it can be seen from figures, the gripper was able to grab a tissue package as well as soda can. As a bonus, rubber has a high coefficient of friction, which helps in enhancing the gripper's strength.

Figure 4. The Humanoid Gripper in action

4.2. Hand Gestures.
As it can be seen from figures, the gripper was programmed to make several gestures, in each of these gestures; the controller would move all the fingers concurrently.

(a) Piece (b) Fist (c) Rock (d) Pointing (e) Waving

Figure 5. The Different gestures achieved by the gripper.

As it can be seen in this section, the objectives of the work has been met, this gripper is light weight, relatively flexible, and is able to grip up to 1kg of weight.

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