Design and construction of an artificial hand

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1 Introduction

The use of a universal grabbing tool can minimize the number of potential necessary special handling tools in robotic applications. Furthermore it minimizes the handling effort by decreasing tool changing times. The human hand can be seen as an optimized, universal grabbing tool. It is optimal in grabbing and holding of things.
The ambition of this research is to grab variable work pieces, variable in direction, shape, surface or consistency. For this purpose we create an artificial hand. This can be installed at an industrial robot. To create an artificial hand studies in the field of forearm structures, motors, joint arrangements and joint numbers, force transmission systems and sensors are necessary.
The basic objective of this work is grabbing a filled plastic cup and a tomato.

2 State of technology

As industrial grabbing tools pneumatic based, based on underpressure to hold an object, are used. Through pressure adaption it can be guaranteed that the object will not be damaged. A further method, widely used in industry, is the usage of double or triple finger grippers. [1]
Among others the company SCHUNK introduced a five finger hand as a universal grabbing tool. Their artificial hand behaves very similar to a human one. It is utilizing nine drives which are based in the carpus. [2]

3 Design of an artificial hand

The human forearm with the hand can be seen as a guideline for an artificial hand. A human hand consists of bones and tendons. The bones are connected over joints. The tendons hold the bones. Muscles, located in the arm, generate the force. The force is transmitted through tendons into the hand. This allows opening and closing of the hand.
To design the components of the hand drives to replace the muscles and bowstrings as power transmission systems can be used. Furthermore, the structure of the human forearm and hand has to be analysed and an artificial replacement has to be constructed. The number and appearance of fingers have to be designed. With a rising number of joints per finger the flexibility increases. But the available room for drives is restricted, so a compromise is necessary. A pressure sensing system has to be incorporated. The structure of the forearm has to provide enough room for drives, control and sensor electronics. The material weight has to be considered but is not an important criteria in the first design.
Several tests with available prototyping machines (3D printer based on selective laser sintering and fused deposition modelling) and simulations have been led to joints with an angel of maximal 35°. A human finger has three joints per finger, leading to a high flexibility. To simplify the system, the last joint of the artificial finger is fixed to 45°, resulting to fingers with two flexible joints. As a consequence the hand can grab mostly round objects. The hand can execute the pinch grip with two joints. In figure 1 a finger with two joints is shown.

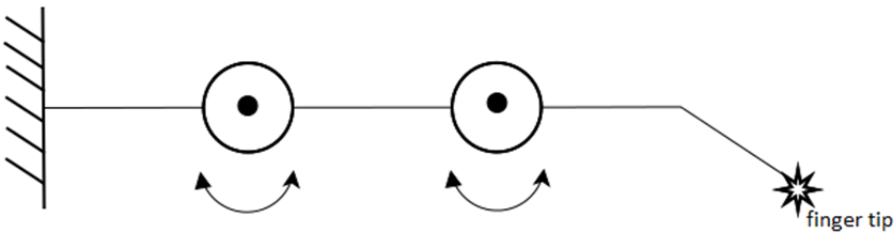

Figure 1: Finger with two joints

At least each fingertip needs a sensor to measure the gripping force. The sensor size has to be very small because of the available space. These requirements can be fulfilled with strain gauges. Passive force sensors change their resistance by strain. These sensors are available in a very flat shape (from 0,35 mm).

4 Simulation of KUKA KR3

The KUKA KR3 is an industrial robot with six rotatory axes. It is installed on top of a working platform. With a weight of 53 kg it can move objects with up to 3 kg. [3]
A simulation is a straightforward way to test and visualize complex movements before executing these in real. In our project it is advisable to simulate the system because of the damageable artificial hand. For this the MATLAB KUKA KR3-toolbox has been used. [4] The toolbox visualizes the robot with graphical surface objects, as shown in figure 2. The software can virtually execute movement commands in a similar way as the real robot is doing. After simulation the real KUKA KR3 can be controlled by the same toolbox.

5 Combine the artificial hand with the KUKA KR3

The artifical hand is mounted on top of the KUKA KR3. The fitting point is the original TCP as shown in figure 2. A TCP is a specific coordinate used in all robotic movement commands. With the mounted hand this point is moved to new TCP as shown in figure 2. Our control mechanisms e.g. to move an object to a specific space coordinate need to use this new TCP. The robot control commands are based on the original TCP. The transformation between these coordinates is done by the MATLAB toolbox.

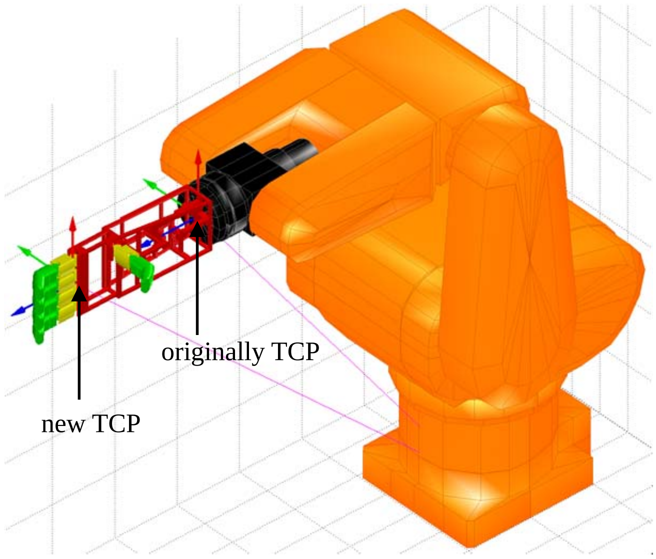

Figure 2: MATLAB toolbox in combination with the hand

6 Collision detection

The KUKA robot has an internal collision detection system, which protects its own movements. The artificial hand is an additional actuator, not known by these internal control mechanisms. That's why an extension of the built-in collision detection is necessary.
To calculate the distance between actuator and robot, spheres are drawn over defined points of the robot. These spheres are shown in figure 3. When the new TCP touches these spheres or moves into one the movement is stopped. A second collision potential is the working platform. This collision is prevented by calculating the height of the new TCP above it. This value is not allowed to go below a minimal altitude.
Because robot and hand are controlled through the simulation toolbox, each movement is checked by the toolbox before it is executed in real.

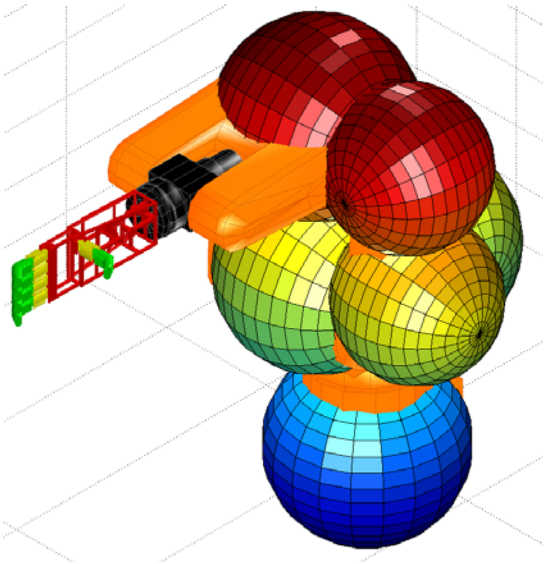

Figure 3: Collision detection

7 Grabbing an object

In [5] several possibilities to grab an object e.g. in dependence of its orientation are analysed. In this research the object is grabbed always in the same way. The KUKA KR3 moves from its home position with an open hand over the object to grab. A second possibility is to open the hand after reaching this position. With the open hand the arm moves down, stops and closes the hand to grab the cylinder (figure 4). During closing the fingertip sensors are checked. When measuring a specific pressure the finger movements are stopped. With the closed hand the robot can hold and move the cylinder within its workspace.

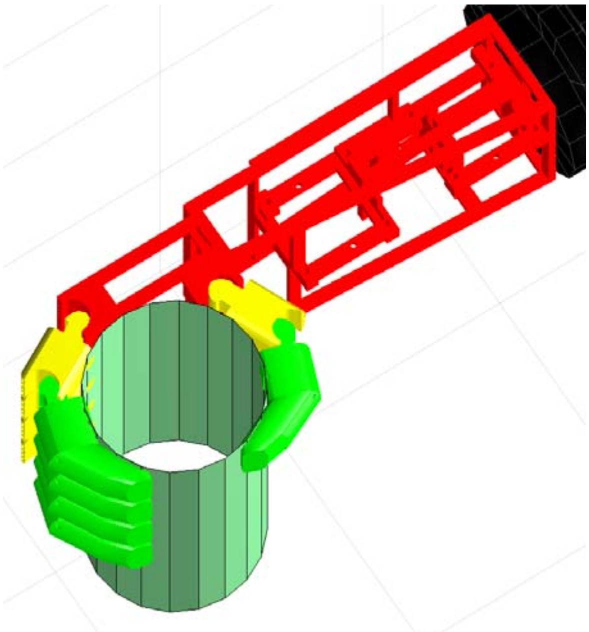

Figure 4: KUKA KR3 grab a cylinder

8 Result

The objective, grabbing of a filled plastic cup and a tomato, without losing or damaging it, can be fulfilled successfully. The actuator has a weight of 304g. It can hold a filled plastic cup with max. 250g. With a higher weight the plastic cup slides out because of too low friction of the pressure sensors. Figure 5 shows the second working prototype of our artificial hand. Two pressure sensors at finger one and two and in the middle of the forearm, motors and electronics can be seen. In Figure 6 the complete test bed is shown.

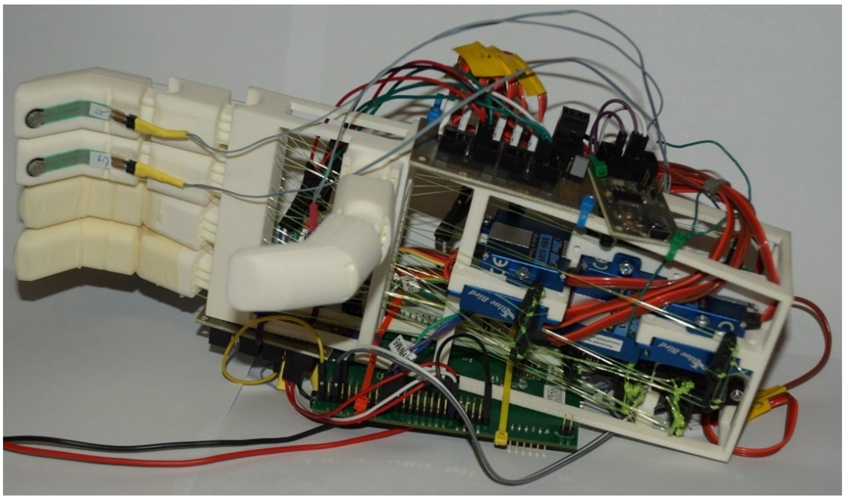

Figure 5: artificial hand

Figure 6: KUKA KR3 with hand

In the following research several points has to be optimized: To increase the weight of objects to grab the friction of the fingers has to be improved. The size of motors and electronics needs to be optimized so that it can be installed completely within the forearm. Also the weight and stability of the forearm structures can be improved. Other grabbing possibilities, as described in [4], will be implemented.

References

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[2] Die erste serienreife 5-Finger-Hand. -http://www.schunk.com/schunk/schunk_websites/products/latest_products_detail.html?article_id=23875&country=INT&lngCode=DE&lngCode2=DE/ (last access: 12/2014)

[3] KUKA KR3 Datenblatt

[4] Toolbox KUKA KR3 - http://www.mb.hs-wismar.de/cea/sw_projects.html

[5] Baier-Löwenstein, T., *Lernen der Handhabung von Alltagsgegenständen im Kontext eines Service-Roboters*, Dissertation Universität Hamburg, 2008

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