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Gripping in anthropomorphic robotics

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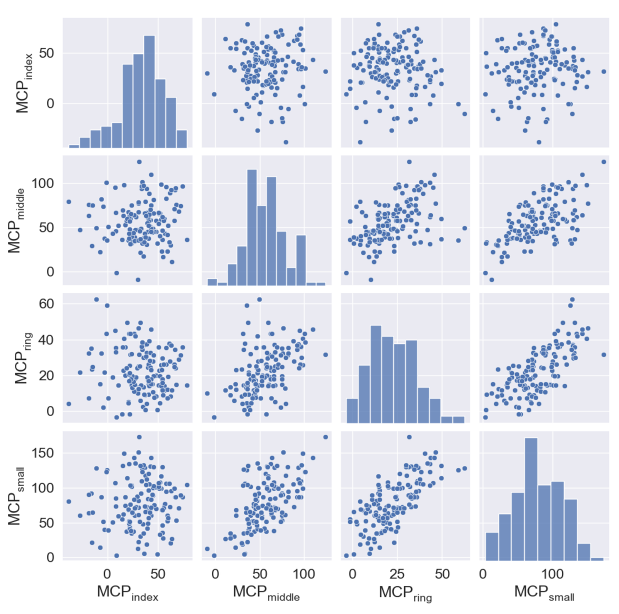
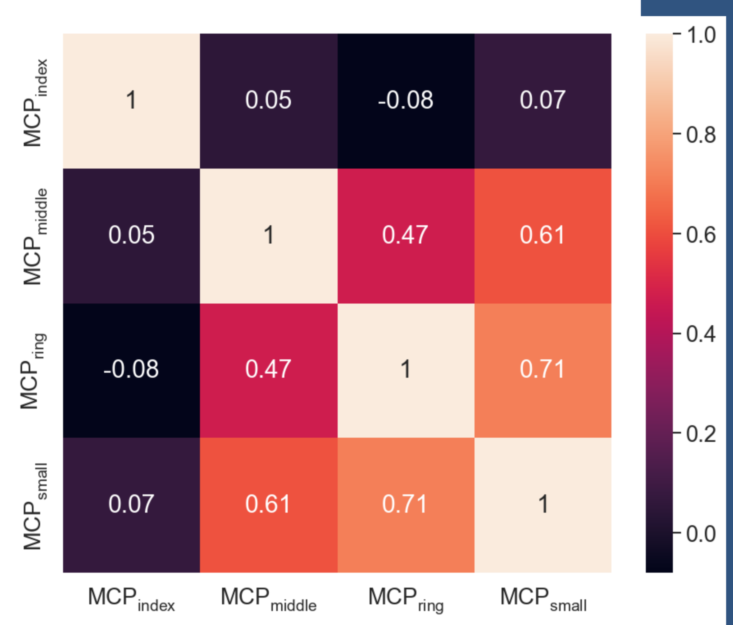
1. Introduction

There has been a growing interest in robotic hand development in the recent decades. In most gripping applications, the gripper is designed to fit exactly one object. This process is not efficient because the grippers are not sufficiently versatile. Most industrial grippers have been limited to specific purposes that are inadequate when dealing with objects of different sizes and shapes. The goal of this project is to provide a starting point for improving industrial robotic grippers in terms of dexterity and the ability to grasp different objects with the same gripper.

2. Data analysis

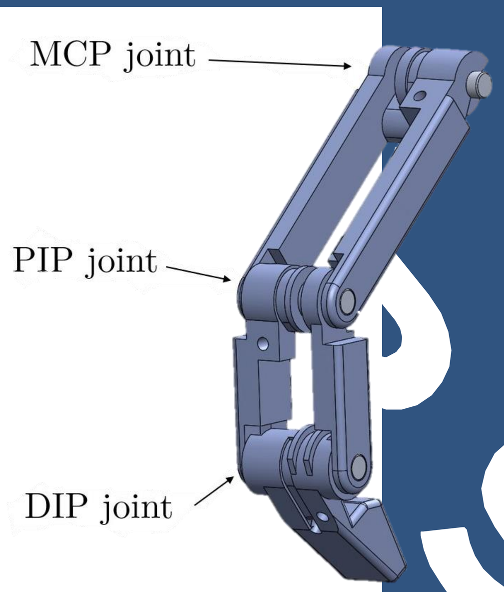
A kinematic analysis of the human hand is performed in order to understand which elements in the human hand are crucial for gripping various objects. The objective is to derive design simplifications from this gained knowledge, which then are used for the robotic gripper. Also, the complexity of the human hand should be reduced while maintaining its high dexterity. The Ninapro database, a publicly available database containing extensive kinematic recordings of the human hand, is used for this analysis. The data are preprocessed and then evaluated to search for kinematic correlations. This is done by setting up covariation patterns among the joint angles and calculating correlation coefficients.
Results of the analysis show a variety of correlations that lead to simplifications of the human hand for the robotic gripper design. These include removals and adjustments of multiple joints.

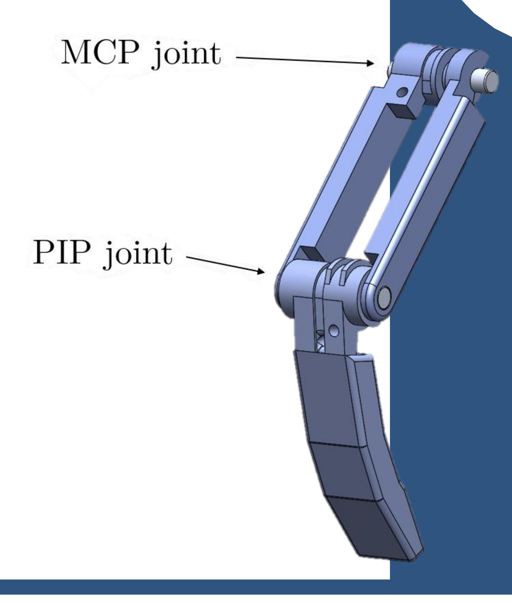




3. Design of the robotic gripper

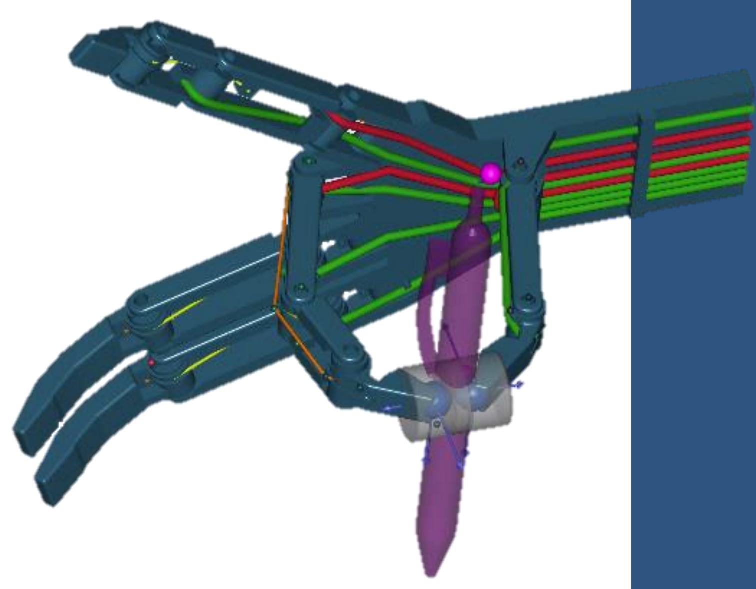
From the simplifications found in the Data analysis, a mechanical solution is designed. This robotic gripper is divided into four main modules, namely precision and power fingers, thumb and palm. The precision fingers (upper figure) act as the index and middle fingers of the human hand. A rotational dependency is created between the DIP and PIP joints using a cable attached to both joints. The power fingers (lower figure) correspond to the ring and little fingers of the human hand. These are mostly used for power grasps. The DIP joint is then removed to simplify these fingers, and a dependency is also present between the two remaining joints. The thumb is also simplified in the same way but no dependency is created. The last module is the palm where all the previous modules are fixed to it. To move the segments of the fingers, the gripper uses a cable-driven mechanism.





4. Simulations

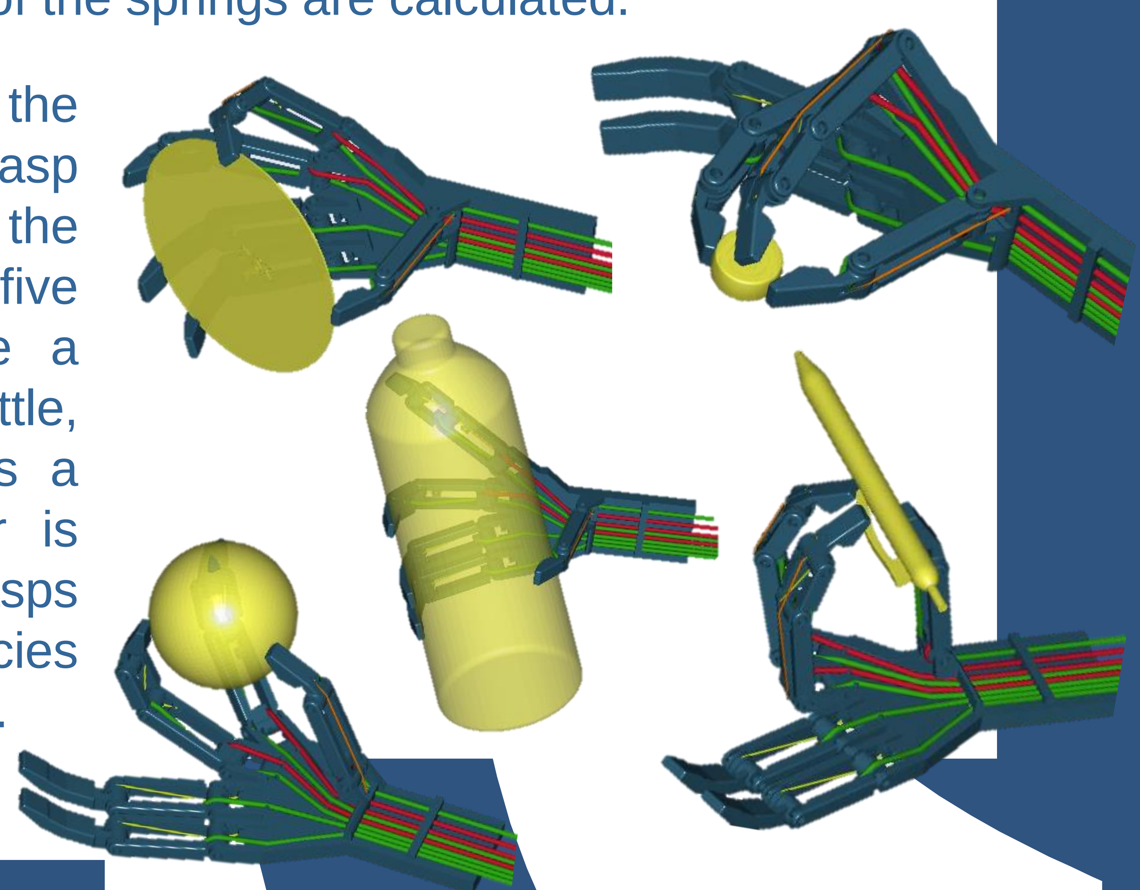
A simulation model is constructed to evaluate the solution's performance and to determine appropriate components such as the cables and springs.



AnyBody Modeling System (AMS) is used to perform static analyses of two grasps: a power grasp of a water bottle and a precision grasp of a pen. These objects can be seen as the maximum and minimum object volume that the robotic gripper can handle. The contact between the gripper and the object is modeled by considering a static friction coefficient of 0.1 and a normal force of 60 N. The latter is close to the value of the pinch force for a man. The maximum involved force is found to be 241 N for a cable in the thumb. Thus, based on the assumption that the cables are in Nylon with a strength of 90 MPa, the minimum diameter is 1.85 mm.

The springs localized on the outer side of the robotic gripper are assumed to be linear. The springs must maintain the gripper on its initial position and balance the gravity forces applied to the components. Using an inverse dynamic operation, the values of the pre-loads and the stiffness of the springs are calculated.

To evaluate the ability of the robotic gripper to grasp different shapes, the simulation of the grasp of five common objects that are a ball, bottle, pen, cap bottle, and a disk is studied. As a result, the robotic gripper is able to perform these grasps with the dependencies implemented on the fingers.



5. Conclusion

The design of a robotic gripper was developed based on the analysis of the Ninapro database. The mechanical solution has 12 joints and eight DOFs moved by independent cables. Four main modules were created to meet the system's requirements while using the simplifications from the experimental data to reduce the complexity of the design. Most of these adjustments are either the removal of selected DOFs from the kinematic of the human hand or the creation of dependencies between joints' angles. The robotic gripper also uses a passive retraction method to move the hand back to its initial position. Finally, using AMS, the actuation system was designed, and it has been confirmed that the robotic gripper is able to perform motions corresponding to the grasps of several objects.

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