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Design proposal of the robotic arm for the mechanical arm of the MechateRobot

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Abstract: The article describes the design and actual production of the robotic arm for the MechateRobot mechanical arm. In the first chapter of the article, there is a description of the design solution, which was created in the Inventor Professional program. In the next chapter, there is a method of manufacturing the structure using 3D printing and a demonstration of the complete assembly of the robotic arm.

1 Introduction

In recent years, there has been tremendous progress in the development of robotic arms. Basically, any device used to move objects can be described as a robotic hand. We can meet this product in industry, where robotic arms are used for welding, painting and other jobs that require precision. Nowadays, there are many robotic hands and arms available on the market, which differ from each other in terms of construction, the material they are made of, the variety of end effectors and, last but not least, the price. As robotic hands are increasingly used in various industries, such as industry, medicine, science or gastronomy, they are still being developed and constantly improved.

2 Structural design of the robotic arm in the CAD system

The design of the robotic arm was based on an already existing robotic arm, to which it was necessary to design the rest of the functional arm. During the design, several variants were solved, which were gradually adapted and improved until the selected variant (Figure 1).

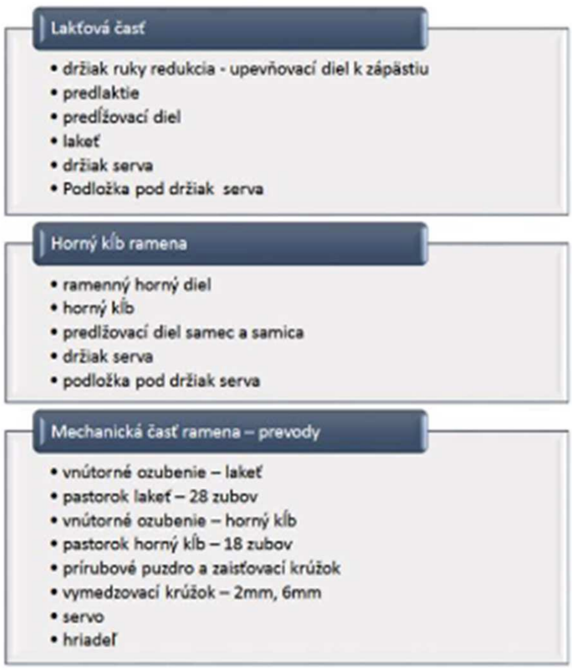

Figure 1 Parts of the proposed robotic arm [1]

Elbow part

The hand holder - reduction, is actually a fastening part for the wrist. It was adapted to the already made parts of the wrist so that they could be connected. The following images show the step-by-step modeling of the hand holder. In the last part F of picture no. 1 (Figure 2), the hand holder is finished [1].

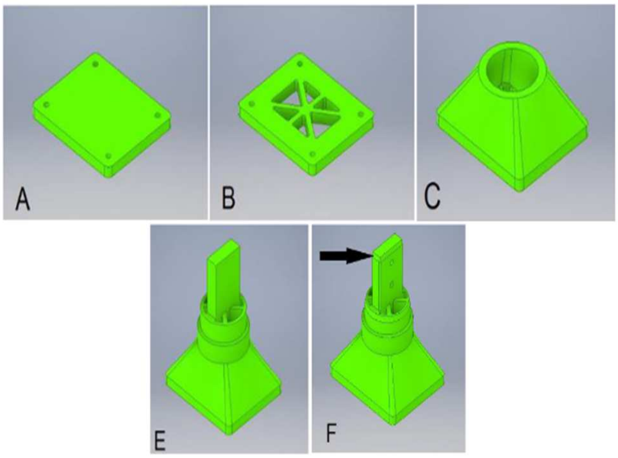

Figure 2 Hand holder - reduction [1]

Forearm

The part of the forearm is designed so that it can be extended to the required length of the arm and the servo drive is attached directly to it. This part of the forearm will house the lower arm gear. Already finished modeled part found in picture no. 3 (Figure 3) [1].

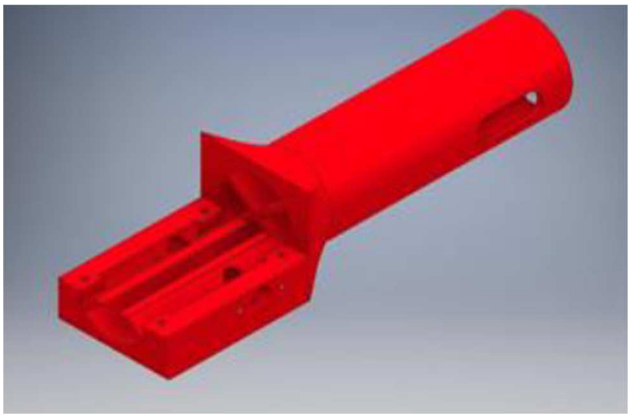

Figure 3 Forearm [1]

Extension piece

Extension part, picture no. 4. it is designed in such a way that it can be made to the required length at any time and attached to an already existing part, thus extending the forearm or upper shoulder part to the required length. This extension piece consists of two parts, namely "male" and "female", which will ensure its easy connection. As shown in picture no. 4 (Figure 4), the connection of the green part and the orange part creates a total extension part. The length of the green part "female" can be easily and quickly adjusted to the desired length in the CAD system [1].

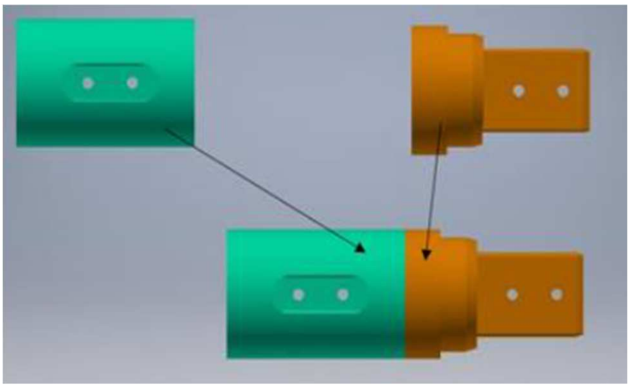

Figure 4 Arm extension [1]

Elbow joint part

Picture No. 5 (Figure 5) shows the elbow part of the arm. His design was since it would be possible to place a gear mechanism in it, that is, also part of the forearm, and that its shape would allow rotational movement. The first variant of the elbow part was later shortened because its length exceeded the capabilities of the 3D printer [1].

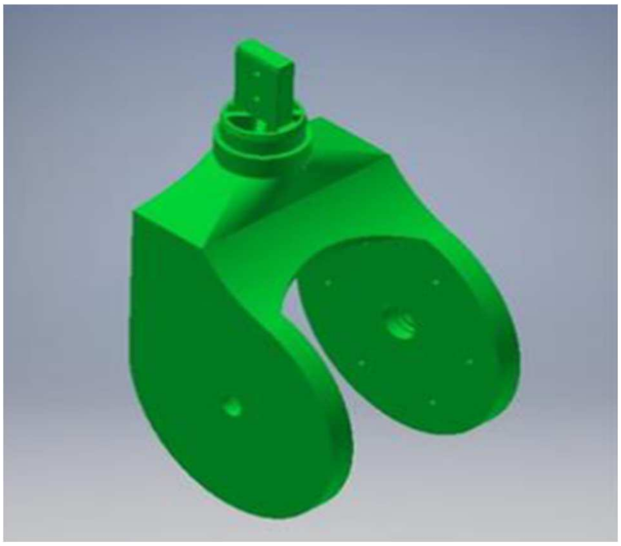

Figure 5 Elbow part of the arm [1]

Elbow joint transmission

To solve the gearbox on the robotic arm, several possible gears were considered, as well as gears, which are used to transfer the torque from the drive shaft to the driven shaft without slippage. And since in our case we have a small axial distance, it was decided to use a gear with internal gearing with straight teeth [10]. Picture No. 6 (Figure 6) shows the entire elbow joint with bearings, axis, precise positioning of the axis and internal gear. CAD program Inventor Professional made it possible to simulate the exact placement of individual parts and thus avoided the risk of inappropriateness or size of certain parts or components [10] The external part of the crank gear with internal gearing has 80 straight teeth and internal gearing – the pinion has 28 straight teeth. For simplicity, the shaft is made from M5 threaded rod, which is held in shaft holders and single row ball bearings "625 Z2" on both sides of this elbow part [1].

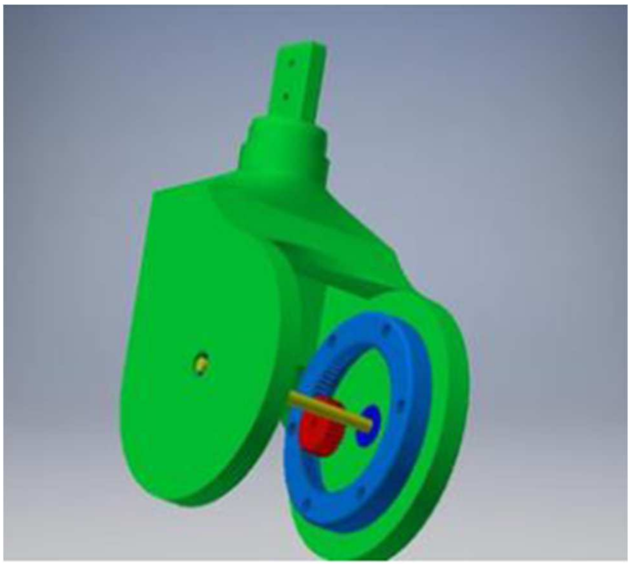

Figure 6 Elbow with gear [1]

The following picture no. 7 (Figure 7) shows the shaft of the elbow joint, which is identical to the shaft of the upper part of the arm. These parts are located in identical shaft holders (shown in green in the picture), later attached with screws to the forearm and upper arm (not shown), with the shaft holder part inserted in these parts. The shaft is placed at its ends in a ball bearing (blue color) and is secured against axial movement by limiting rings (orange color) [1].

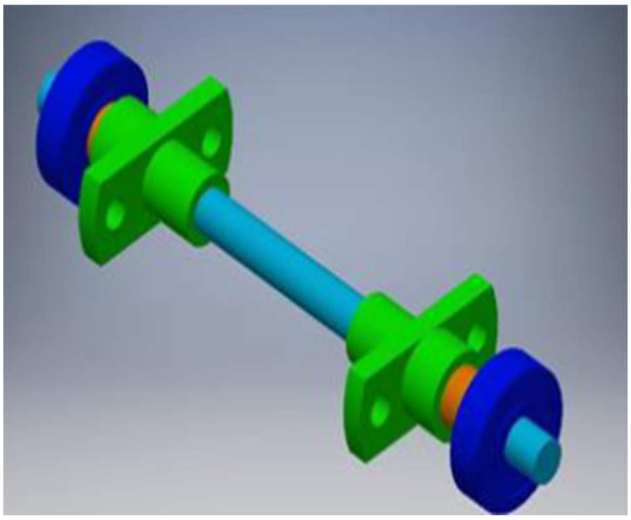

Figure 7 Shaft, bearings, and definition of bearings [1]

The placement of the shaft with bearings and holders in the forearm is shown in picture no. 8 (Figure 8). The fastening holes can also be seen. The shaft holders are designed for easier replacement.

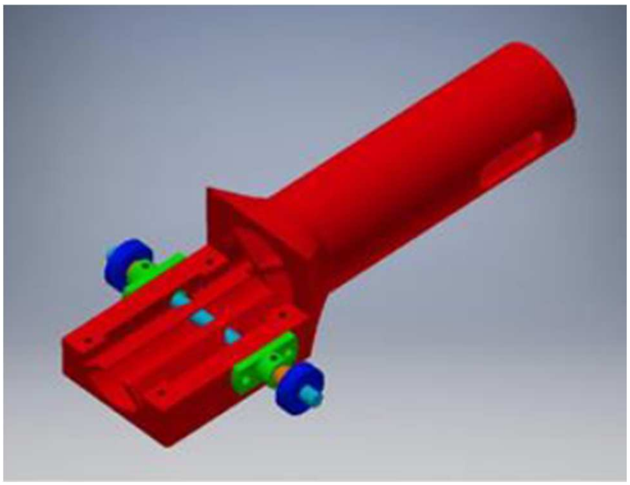

Figure 8 Forearm with servo [1]

Forearm actuator storage

Picture No. 9 (Figure 9) shows the entire forearm with the hand holder, servo motor, servo mounting on the holder, shaft with bearings and gear wheel on the shaft.

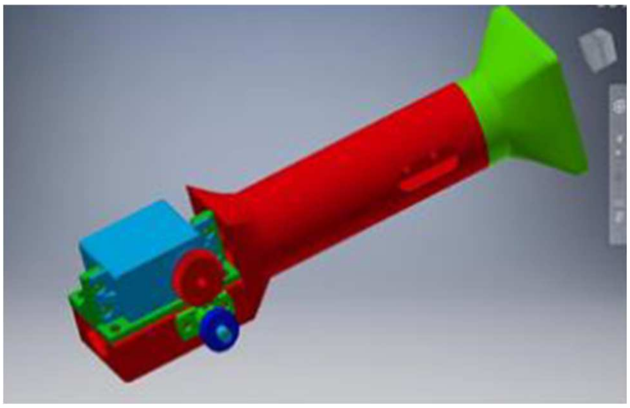

Figure 9 Forearm with servo [1]

The second part of the arm

The upper part of the arm. In picture no. 10 (Figure 10) is a modelled part of the upper arm of the hand.

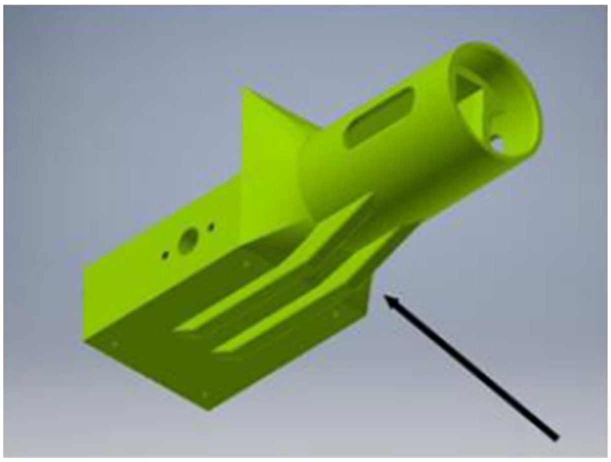

Figure 10 Upper arm [1]

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Its shape is like the part of the forearm, it is distinguished by the location of the axial distance. In the lower part, the reinforcement of the part is visible, as well as the holes for the shaft, holes for fixing the shaft holders with screws. The following picture no. 11 (Figure 11) shows the axial distance on the upper arm, which is different from the axial distance of the axis on the lower arm of the arm.

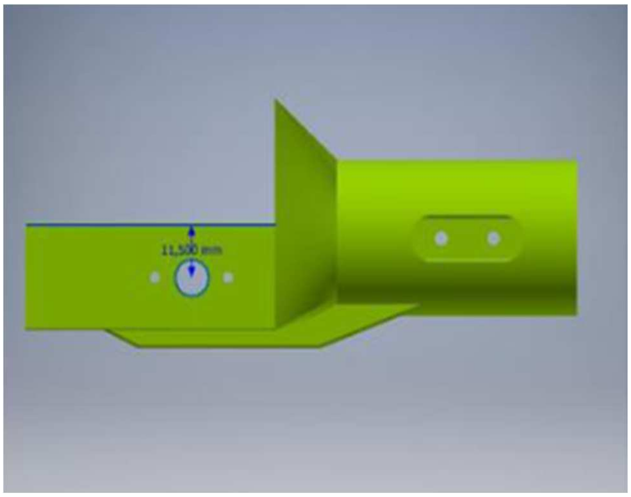

Figure 11 Axial distance of the upper arm [1]

Positioning of the upper joint servo motor Figure 12 shows the upper arm together with the servo, shaft, bearings, and gearing. The placement of the servo on this part differs from the placement of the servo on the forearm in two points. One of them is the axial distance between the axis of the servo and the axis of the shaft around which the arm rotates. The second difference is the rotation of the servo by 180°, this rotation ensured that the axial distance increased even more and with the help of this modification it was possible to achieve the required transmission ratio and thus ensure the use of servomotors with the same power for both parts of the robotic arm [1].

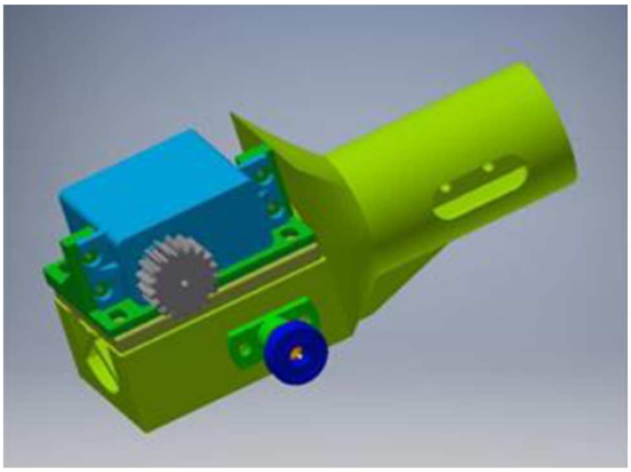

Figure 12 Upper arm with servo [1]

In pictures no. 13 (Figure 13) is the gearing of the upper joint and the illustrated transmission of this joint together with the servo. Due to the insufficient axial distance for the required transmission, it was decided to use a spur gear with internal gearing with straight teeth. In this case, a 90-tooth wheel was used, and the pinion has 18 teeth. Since the necessary movement of the arm was determined in the range of up to 180°, it was not necessary to use the entire complete circular toothing, as in the case of the elbow joint, but only half of it. With this modification, it was possible to reduce the size of the upper joint part - "upper shoulder joint". Four holes for screws were modeled on the gearing to connect the internal gearing and the upper joint part [1].

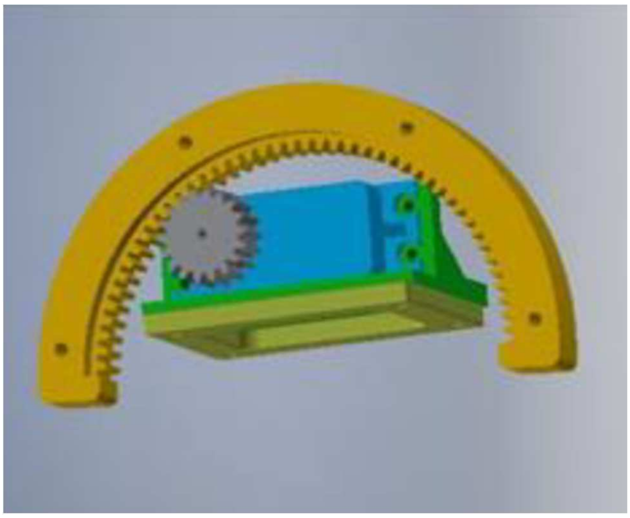

Figure 13 Transmission of the upper joint [1]

Upper shoulder joint

The following pictures show the step-by-step modeling of the upper joint. Image no. 14 (Figure 14) shows the base for the upper joint - the side walls of the joint with holes for the axis, holes for mounting the bearings and holes for the screws of the transmission gear.

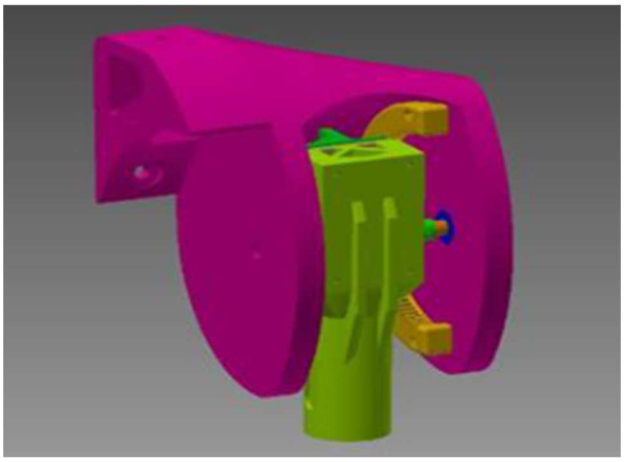

Figure 14 Upper arm joint [1]

3 Production of the arm using 3D printing

The individual parts of the arm of the robotic arm were printed on a 3D printer in the laboratory of the Technical University in Košice (Figure 15). As already mentioned in the previous chapters of the article, the individual parts were constructed in the CAD system in the Inventor Professional program and then saved in an STL file, which is supported by a 3D printer. In this way, all the constructed parts were gradually modified and printed. The ABS material and PLA fiber were used for printing.

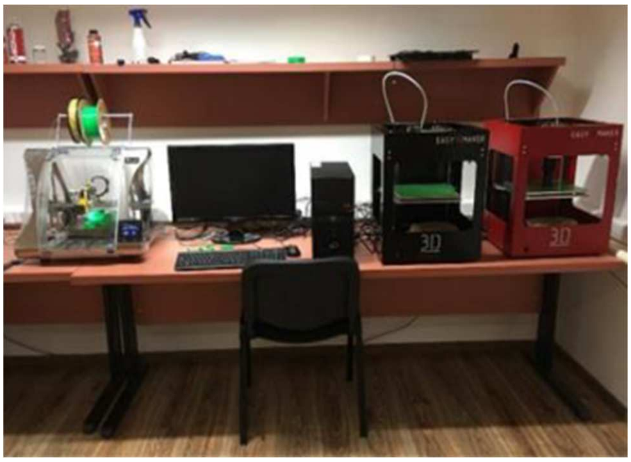

Figure 15 Laboratory with 3D printers [1]

Since this is a prototype, the individual parts of the hand were printed in different colors for better visualization. Figure 16 shows all the parts of the arm that needed to be printed on a 3D printer.

Figure 16 Arm parts printed on a 3D printer [1]

Arm drive

The SRT-DL3017 DC servo motor was chosen for the motion mechanism of the robotic arm, its specification is in table no.1. The main reason for choosing this servo with maximum traction with a load of 17kg.cm, the high weight of the end effector with its movement device (wrist) reached almost 700g and considering the total length of the proposed robotic arm together with the mentioned end device reached almost 70cm. [3]

Table 10 Technical parameters of the servo motor [3]

Dimensions	40.7x20.5x39.5 mm
Weight	63,0g
Bearing	dual
Operating frequency	1520us/330hz
Work stress	DC 4.8 – 6V
Working speed (4.8V)	0.17s/60 degrees without load
Working speed (6 V)	0.15s/60 degrees without load
Traction load (4.8V)	15.5kg.cm
Traction load (6 V)	17.0kg.cm
Potentiometer drive	Direct drive
Cable connector length	JR 250 mm
Gearbox material	Titanium and brass

And finally, in the last picture no. 17 (Figure 17) is a complete robotic arm of the MechateRobot hand placed on the also proposed stand.

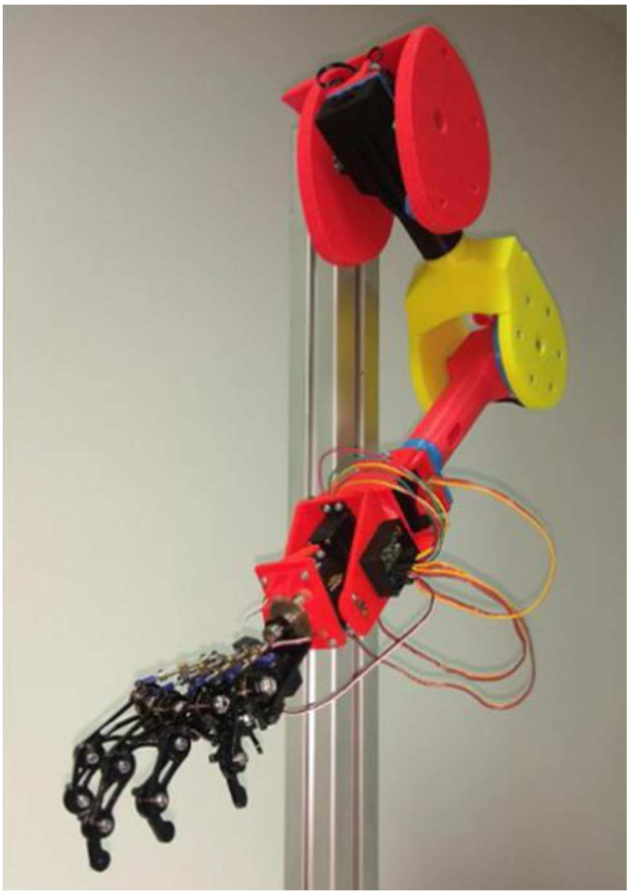

Figure 17 Robotic arm MechateRobot [1]

4 Conclusions

The goal of the design was to create an arm model for the MechateRobot robotic arm. The method of additive 3D printing technology was chosen to produce the model. The robotic arm should serve for animation purposes and movement simulation during the teaching process or research. After assembling all the parts, a fully functional model of the robotic hand was created. Each of the degrees of freedom allows the robotic arm, which is attached to the wrist, to simulate its function identical to that of a human hand. This increases the significance of the MechateRobot robotic arm in animation and its potential use in engineering and educational practice.

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