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3D PRINTED HUMANOID HAND

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Abstract: *An original design of a humanoid hand created by a 3D printer is presented. A concept for directly printing the fingers of the hand as one connection which reduces the time for the assembly operations and improves the repairability. The hand is controlled by a sensor glove. The mechanical and also the control systems of the hand are presented.* 3d Printed Humanoid Hand can be applied *for student's education*.

Key words: *Humanoid Hand, 3D Printing, Education*.

1. INTRODUCTION

A lot of the robots are made to manipulate with different types of objects and for this reason they also have various types of end effectors. One of the gripping problems is the flexibility according to different objects which has unique shape, geometry and are made from specific material. The end effector should adapt itself about the position and orientation of the object [1].

Movement in nature are based on a mechanical system which is made from links with complicated 3D space shape – bones which are driven by elastic elements muscles. The development of the 3D printing technologies increases the interest of research and creating of humanoid robotic hands which are closer to the biological analogues[2-5].An electrical system is used to driven da hands and the muscles and tendons are represented by wires [6,7]. Experiments with various shapes and types of joints for fingers of the hands are made and also 3D printed elastic elements are used [2,3].Some researchers are focused on different methods of grip and manipulation with objects and finger configurations [8].Some of the developed hands find application for prosthesis[3] and rehabilitation [9].Another are used by the humanoid robots. Different achieves are used in a way to simplify the design of the models[10].The development of the control systems allows the usage of the myoelectric control for some prosthesis[9].For the remote control cases the humanoid hands are using both some algorithmic programs and also sensor gloves for movement realizationя [10].

From the analysis mentioned above, the following problems are still unsolved:

-One of the fundamental problems in the design of the hand is the realization of many degrees of freedom in small volume (about 500 cm^3) and also consideration with the requirements for low mass. The development of the technologies, connected with the driven systems allows the fabrication of small size components but still it is very hard so many mechanisms to be put in such small volume which is the hand. Furthermore, a system with a lot of electro motors becomes complicated for control. It is required for the sources of energy to be with small sizes and high reliability.

- The diversity of the movements humans could do with their hands are also hard to be represented by a mechanical designed system.

- A great part of the gestures are connected with complex precisely coordinated movements of the fingers. In this case, it is necessary the trajectories to be described or velocity control to be done. A precise servomotors and specific algorithms for control are used.

-There are also some problems with control system, including: an appropriate microcontroller which could control a lot of servomotors, has a suitable interface for computer communication and is reliable enough.

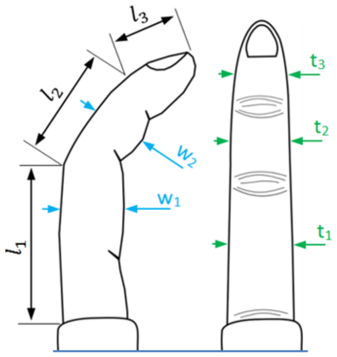
- Important point is the compactness of the control board which is usually pasted nearby the humanoid robotics hand.

- Issues with the reliability of the components: The mechanical system is often very complicated and consists a lot of detail in order to satisfy the requirements of the difficult three dimensional space movements of the hand which decreases the reliability. For movements transfer in higher distances, often are used wires or, fibers and elastic elements [6], which could change their properties and quality in time.

In this paper the realization of an idea of 3D printed hand is discussed. Different options for control and application of the hand are also shown [11].

The dimensions of the human fingers are individual and could vary, see the average values at Fig. 1.

The opportunity for creating customized object with complicated geometry is a reason for using 3D printing as an appropriate method for building a humanoid hand.



d	mm
l_1	47
l_2	26.7
l_3	21.8
t_1	17
t_2	15.5
t_3	14.7
w_1	19.1
w_2	14.7

Fig.1. Dimenssions of a human finger [3].

2. DESIGN OF THE HAND

An original idea of 3D printed humanoid hand which fingers are directly printed as one assemvly is presented [13].On the base 1 are are located the servomotors 2 (MIRCO SERVO, Model No. HD-1581HB, Reduction ratio 1/522). On the shafts of the servomotors 2 are assembled the rolls 3(Fig.2).

The tendons 4 are connected to the rollers 3 and goes through holes in the fingers 5. The other end of the tendons is static captured to the last links 6 of the fingers.

Fingers 5 are connected with the base 1 with screw connection 7. The shape of the joints for each finger consists of two cylindrical parts 8 and one spherical part in the middle 9, as it is shown at Fig. 3. The innovation of the proposed model is that the fingers (parts 6,8 and 9) are printed whole.

The 3D printed elastic element 10 is constrained in its one end with the external joint 6 of the fingers 5. The other end of the elastic element is connected through the base 1 with the screws 7.

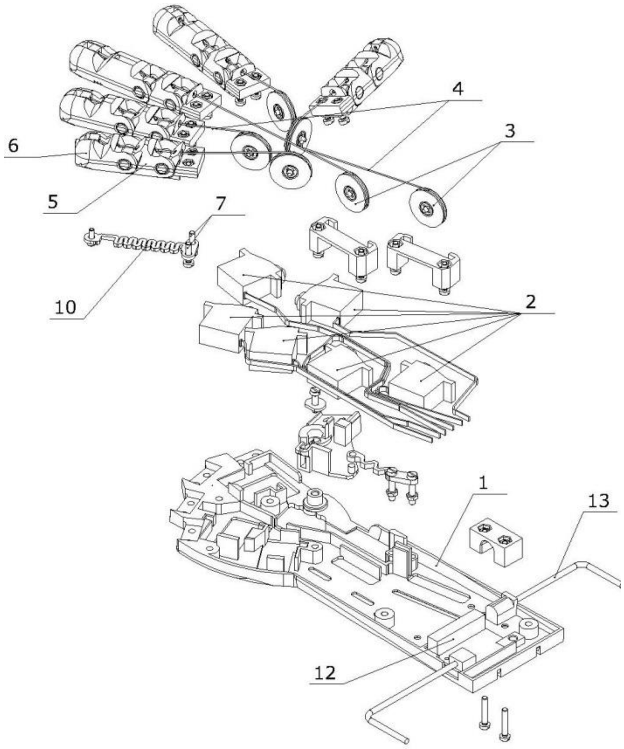


Fig. 2. Basic components of the hand.

The elastic component 10 is disposed on the outside of the fingers.

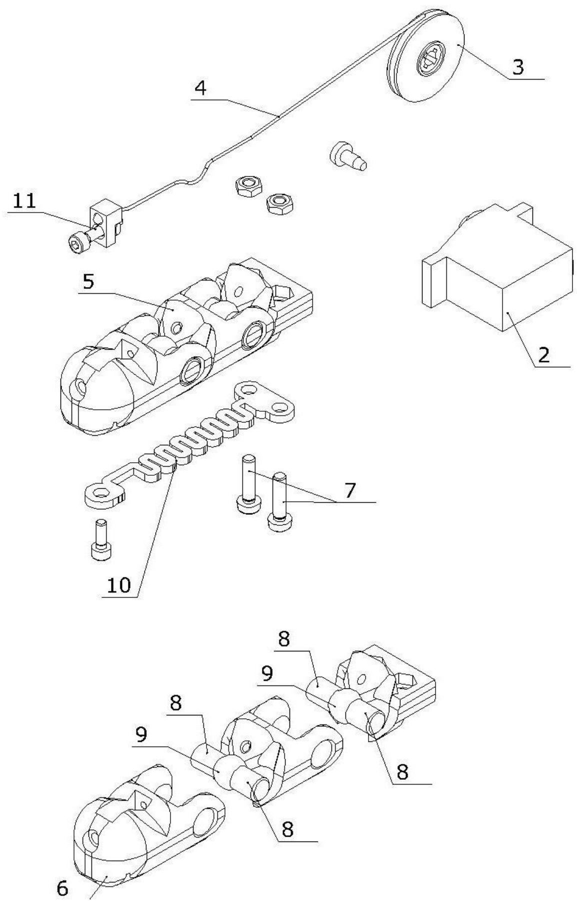


Fig.3. 3D modelof a finger

The joints of each finger have minimum clearances between the cylindrical 8 and spherical 9 surfaces and in this way they are directly printed as one assembly. In the external link 6 of each finger 5 exists a screw connection mechanism 11 for controlling the tensile force of the tendon 4.

The control of the motors is realized by a computer which sends signals to the drivers 12. The communication could be done wireless or via cable. The energy source for the motors and also for drivers comes from the power supply 13

The elastic element 10 is printed from a special material – Filaflex for 3D printer. The most appropriate elastic properties of the elastic element 10 are experimentally defined by changing its width and thickness. The tensile of the fibers is controlled by the screw mechanisms 11 (Fig.4).

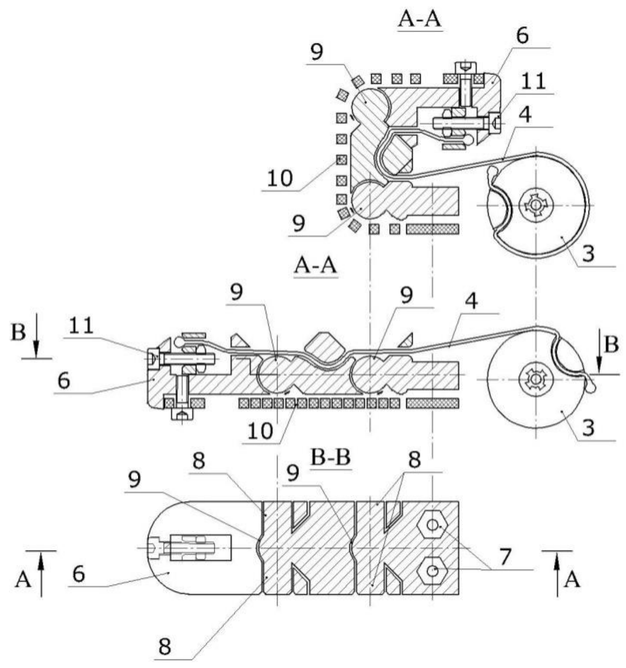


Fig.4. Structure of the hand’s fingers.

On Fig. 5 is shown a prototype of the 3D printed hand.

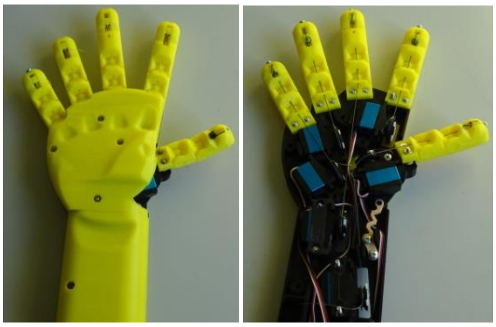


Fig. 5. General view of the 3D printed hand.

Each finger of this hand has one joint and one link less than the real human hand because of the small stroke of the servomotors and also the limited volume of the palm.

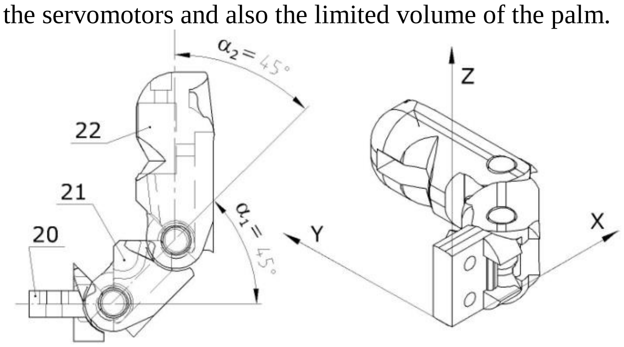


Fig. 6. Location and orientation for printing of a finger.

Link 21 is rotated according to link 20 on angle $0 \leq \alpha_1 \leq 90[deg]$, and 22 referred to 21 on angle $0 \leq \alpha_2 \leq 90[deg]$.

For fabrication the hand is used FDM 3D printing technology. For the correct fabrication of the finger, it is recommended to be located parallel to the working plane (bed’s plane) XY and the links 20, 21 and 22 should be located half bended one to anotherFig.6. The clearances in the joints are defined experimentally.The fingers, created this way have good agility in the joints.

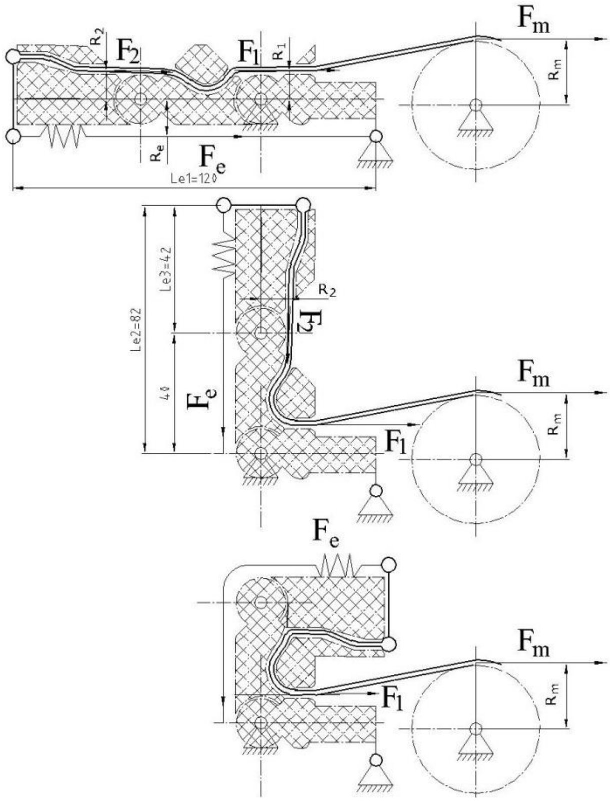


Fig. 7. Stages in the fingers movement and location of the forces.

The driven moment from the servomotors creates tensile force $F_m$in the fibber (Fig.7). This force is counterbalanced with the force of the 3D printed spring:

$$F_e = k \cdot L_e \,. \tag{1}$$

where k is the elastic coefficient of the 3D printed spring and L_e is the length of the working area of the spring. Depending from the distances R_1 and R_2 on which the forces F_1 and F_2 acts, it is possible one of the elements 21 or 22 of the fingerto be driven. In the case when $R_1 = R_2$, first 21 is rotated on 90 [deg], and then 22 rotates. F_2 is less than F_1because there are more friction loses. The length L is time variable and depends from the joint restrictions.

3. CONTROL OF THE HAND

The microprocessor electric drive is carried out by means of Arduino Nano based on the microcontroller ATMEGA328 with embedded USB interface for servo drivers control.

Because of the high energy consumption it is necessary to use external power supply. The electrical scheme of the microprocessor’s electrical motion is given at Fig.8.

For generating control signals a sensor glove is used. The electrical scheme of the glove is **shown on Fig. 9.**

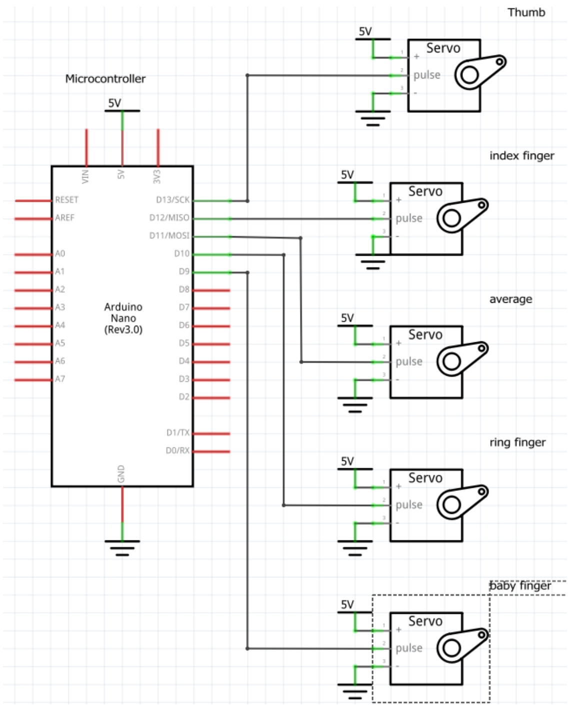


Fig. 8. An electrical scheme of the microprocessor’s electrical motion

The glove is used as a control device. It could define the movements all five fingers by tensor resistors and communicates via USB and UART interface.

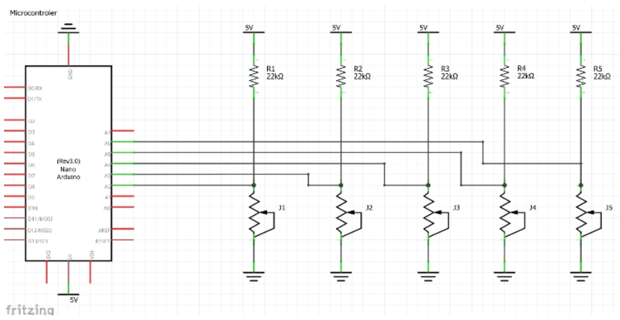


Fig.9. An electrical scheme of the glove.

As a programming language for development is used Python in the programming environment PyCharm. The library for developing the graphic user interface is tkiner. This allows the application to be used on several platforms and also to work on different operational systems.

It is a low cost development and it is easily available. Because all of the fingers are driven independently, it is easy a lot of finger combinations to be realized. In this way some gestures as counting could be represented. The hand is driven from six motors and two of them are used to drive the thumb. This allows realization of more complicated gesturers, for example contact between the thumb and some of the other fingers.

Fig.10. Application of the hand.

The configurations and set up settings are specific, depending from the application.

This research is made in cooperation with high school students from a specialized computer technologies school **(**Fig.10). In this application the students demonstrate their knowledge and skills in the field of software and hardware technologies.

4. CONCLUSIONS

An original mechanical construction of a humanoid robotic hand is designed. A 3D printed prototype is created, too.

An original conception for directly printing the fingers as one assembly is used. The advantages are: modularity, reduces assembly operations, improves reliabilityand the robotic hand is easily repaired. It is experimented with several different designs for the fingers of the hand.

The control system, realized by a sensor glove has the advantage of remote control as well as to make records of the hand movements sequence.

This model could be used for some applications connected with the language of gestures – as an independently working system or part of a humanoid robot.

The prototype is appropriate for usage for high school education in the field of computer technologies and programming. In the development of the hand high school students are taking part working on the hardware and on the software as well.

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