RESEARCH ON SMART PROSTHESIS PRODUCT DEVELOPMENT

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ABSTRACT: Finger and hand amputation are one of the most common amputations in the world, in this project it will be presented a solution for this problem.

KEYWORDS: prosthesis, design, sensor

1. Introduction

The history of amputation and prosthetics probably begins with the first instance in which a human being lost a limb and sought a replacement. Worldwide, the recorded history of amputation and prosthetics begins with Herodotus' account of a Persian soldier escaping from captivity in 484 BC by cutting off a leg and replacing it with a wooden one. The history of amputation, and therefore of forearm and hand prosthesis in Romania, begins, in terms of recorded sources, about a century ago.

At present, several products are being designed to replace the human hand, most of which are in the testing stage.

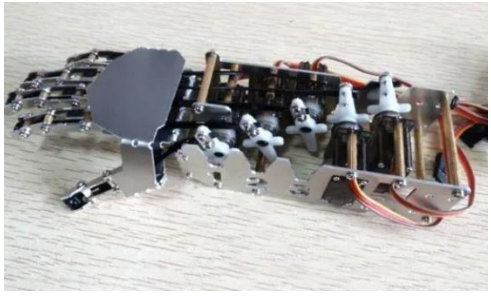
(History, 2021)

2. Current status

Today, there are many solutions to this problem but in most cases they only cover the cosmetic side, not the functional side[1].

In the case of functional prostheses they have an unnatural appearance and in some cases are difficult to use. A table of competing products has been compiled from these solutions, see Table 1.

Table 1 - Identification of competing products

No.	Competing products	Product specifications
1	 DIY 5DOF Robot Five Fingers Metal Manipulator Arm *(Arm 1)*	Mini bionic handheld, innovative and realistic design. Uses five servos to steer, each finger can move individually flexible. Features: Name: DIY 5DOF Robot Five Fingers Metal Manipulator Arm Type: QDS-1601 Age: ≥ 8 years old Weight: Approximately 163g Material: aluminum alloy Model: left hand, right hand Bionic hand size: 181.86*44mm (L*W) Servo size: 27.5 * 12 * 21 mm (L * W * H) Degree of completion: semi-finished product Price: 249,86 lei

No.	Competing products	Product specifications
2	 LOBOT uHand2.0 DIY RC Robot Arm Independent Fingers With LFD-01 Anti0-block Servos *(Arm 2)*	Brand: LOBOT Product: uHand2.0 RC robot arm Features: - With anti-block servo, better protect the arm. - Arm fingers act independently. - M3 install hole, can DIY to many kinds of robot arm. Battery recommendation: 2S 7.4V 2200mah Lipo battery (not included) Materials: acrylic + aluminium Servo: LFD-01 Anti-block servo Product weight: 184.8g Product size: 165*90mm Price: 337,45 lei
3	 Open Source UNO Somatosensory Wearable Robot Gloves *(Arm 3)*	UNO open source somatosensory wearable robot gloves Features: Built-in Bluetooth 4.0 mode Built-in acceleration sensor etc. Can control robot arm, robot machine. Specifications: Microcontroller model: Battery: 7.4V lipo battery Size: 147*113mm Weight: 260g Price: 388,37 lei
4	 DIY 5DOF Robot Arm Five Fingers Metal Mechanical Paw Left and Right Hand *(Arm 4)*	Description: Name: DIY 5DOF Robot Five Fingers Metal Mechanical Paw Type: QDS1605 Age: ≥ 8 years old Weight: Approximately 380g Material: aluminum alloy Model: left hand, right hand Hand length: 200mm Servo working voltage: 5V-6V Control protocol (TCP): 1.0 ms - 2.0 ms for servo from 0 to 180 degrees Degree of completion: semi-finished product Features: Use five servo to drive, each finger can move individually flexible. Mini handheld, innovative and realistic design. Manipulator is focused on demonstrating action, bringing goods in less than 500 grams. Price: 417,80lei

As can be seen from this table the current solutions have an industrial appearance, not a natural upper limb shape. In the following chapters a solution will be presented that covers both design and functional aspects of a prosthesis.

3. Mission statement for the selected product development

Product description:

- a fixed and mobile prosthesis that takes over the functions of the amputated parts;

Key business objectives:

- *the product is placed on the market on 1 July 2023;*
- *to reach 10% of the prosthesis market by the end of 2025;*
- *selling 1000 pieces by the end of 2025;*

The market:

- *people with disabilities;*
- *medical clinics;*
- *hospital;*
- *army;*

Hypothesis:

- *light weight;*
- *spare parts;*
- *anti-abrasion strip;*
- *easy forearm attachment;*
- *control through the wrist;*
- *100% safe use;*

Interested persons:

- *the user (people with disabilities);*
- *hospitals;*
- *private practices;*
- *medical centres;*
- *production department;*
- *health organisations.*

Matrix for selecting interviewees:

	Top users	Users	Retailers	Service centre
Private offices (occasional use)	2	5	1	0
Hospitals and medical clinics (frequent use)	3	5	2	
People with disabilities (heavy use)	2	10	1	

4. Aspects of strategic marketing

Data collected from potential customers. A questionnaire will be used to identify customer requirements. The questionnaire will contain the following questions:

1. Does the current product ensure the handling of objects?
2. Does the current product provide real-time data?
3. Is the product hygienic?
4. Is it easy to fix?
5. Is it safe to use?
6. Is it a durable product?

7. Is there a danger of limb fatigue?
8. If the product is damaged, what do you do?
9. Would a similar product weighing less be useful?
10. Would it be useful to connect it to your phone?
11. Is the aesthetic or functional part more important?

Ranking and determining relative importance

After studying the answers and interpreting them, a selection matrix was drawn up, in which scores from 1 to 5 were given according to their relative importance.

Table 2. Selection matrix

Customer requirements	**Relative importance**
PM can be used to manipulate objects	5
PM provides real-time data	4
PM is a hygienic product	4
PM has an easy-to-use fastening mechanism	5
PM offers safety in operation	5
PM is a durable product	3
PM ensures physical integrity	5
PM provides repair services	3
PM has a low weight	3
PM can be connected to the phone to access collected data	1
PM looks good and performs as expected	4

5. Setting specifications

According to the competition table presented above a table of characteristics was formed (Table 3).

Table 3. Characteristics of competing products

No.	**Size/character**	**Units**	**Competing products**			
			Arm 1	**Arm 2**	**Arm 3**	**Arm 4**
1	Weight	g	163	184,8	190	380
2	Palm size gauge [L x l]	mm X mm	181,86 * 44	165 * 90mm	147 * 113	200*111
3	Customizable	Yes/No	No	No	No	No
4	Operating time	years	2	2	2	2
5	Temperature resistance	°C	40	55	40	30
6	Clamping force	N	10	20	25	18
7	Maximum load capacity	kg	1	0,8	0,5	1,5
8	Self-tightening function	Yes/No	Yes	Yes	No	Yes

No.	Size/character	Units	Competing products			
			Arm 1	**Arm 2**	**Arm 3**	**Arm 4**
9	Water and dust resistant certification	Yes/No	No	No	No	No
10	Proportional control of speed and force	Yes/No	No	No	No	Yes
11	Adjustable clamping settings	Yes/No	No	No	Yes	No
12	Guarantee	months	12	12	12	6
13	Price	lei	949,86	1333,45	1188,37	417,80

Establishing the list of sizes and the characteristics-requirements matrix for the product

Following will be presented the Matrix of Measurements – Requirements, see Table 4.

Table 4. Size-certainty matrix

Requirements			*Sizes/features*												
		Importance of the requirement	Weight	Palm size gauges	Customizable	Operating life	Temperature resistance	Clamping force	Maximum load capacity	Self-tightening function	Water and dust resistant certification	Proportional control of speed and force	Adjustable clamping settings	Guarantee	Real-time data
			1	2	3	4	5	6	7	8	9	10	11	12	13
1	PM can be used to manipulate	5	●	●				●	●	●					
2	PM has an easy-to-use clamping	5	●		●								●		
3	PM offers safety in operation	5	●	●	●		●	●	●	●		●			
4	PM ensures physical integrity	5		●			●					●	●		
5	PM looks good and works as	5			●								●	●	
6	PM provides real-time data	4				●									●
7	PM is a hygienic product	4			●						●				
8	PM provides repair services	3												●	
9	PM has a small weight	3	●												
10	PM is a durable product	3					●				●				
11	PM can be connected to your phone to access collected data	1													●

6. Detailed design

This chapter will present the concept of the prosthesis and how it is manufactured:

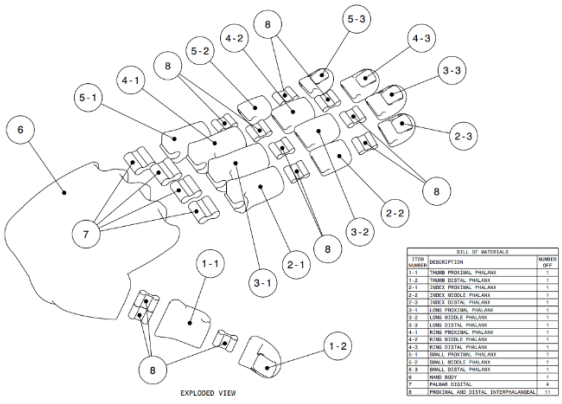


Fig.1 – Bill of materials

Figure 2 shows all the component parts of the prosthesis. Its joints will be made of a flexible material and the rest of the components will be made of a rigid material mimicking the cartilage and bones of a human hand.

The manufacturing method chosen is 3D printing, which is a low-cost solution with high flexibility in terms of materials [6].

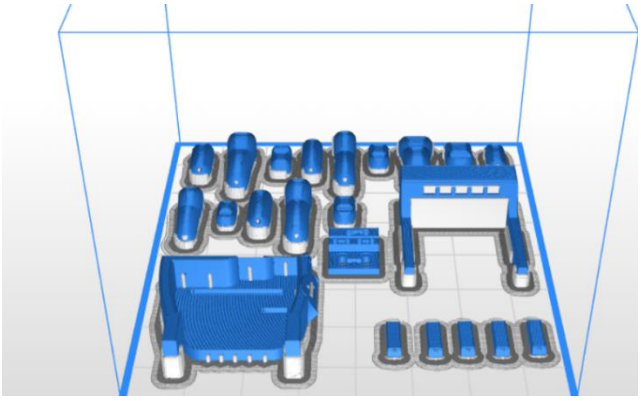


Fig. 2 Print simulation

Figure 2 shows the components on the printer table. In this simulation the z-sheet material was used and the total printing costs were 98 lei.

7. Further developments

In order to improve the user experience of the prosthesis, various sensors are added to the prosthesis to assist the user in everyday activities.

Among the sensors that can be added to a hand prosthesis are:

1. Temperature sensor
2. Humidity sensor
3. Pulse monitoring sensor

The temperature sensor (fig.3) is needed to know the temperature of an object, so there is no risk of touching an object that is too hot.

Fig.3. Temperature sensor

The moisture sensor (fig.4) is used to distinguish between a wet and a dry object. A practical example is washed clothes, where the user can distinguish between wet and dry clothes.

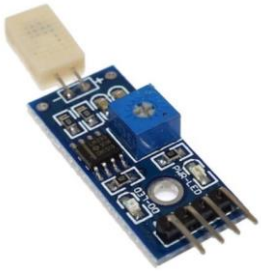


Fig.4 Humidity sensor

The pulse measurement sensor (fig.5) is a function designed to continuously monitor the heartbeat, this sensor is especially beneficial for people with cardiovascular diseases because it can act more quickly in case of heart irregularities.

Fig.5 Pulse measurement sensor

The information provided by the sensors will be displayed on a screen (fig.6) positioned on the wrist.

Fig.6 digital display

8. Conclusions

The main advantages of this prosthesis are:
-low production cost;
-the protector is adjustable and can be used by all those missing one or more fingers;
-data is collected about the objects touched, but also about the user's condition;
-provides safe conditions of use;
-does not require maintenance;

9. Bibliography

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