Creating a Lightweight Exoskeleton Arm

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***Abstract*—Idea of creating a perfect exoskeleton arm that can be created by anyone without the practical limitations has long since been thought off. Basic concepts of exoskeleton usually require external mechanical components added to an external frame, but designing in a sketch can be time-consuming and difficult to measure or model accurately in 2D-space. Using a computer-aided design(CAD) one can model accurately and remove the limitations or flaws by visualizing the 3D-model to allow for rapid creation of prototype arm. In this paper we have managed to successfully create a lightweight exoskeleton with a DC-motor in a prototype phase for further development.**

Keywords-- Exoskeleton, CAD-model, 3D-model

I. INTRODUCTION

The term exoskeleton often refers to as a wearable mechanical device that allows and grants the user some unique characteristics. This is made possible by creating an external frame that combines various mechanical components such as hydraulics, actuators, sensors and so forth. These characteristics can vary from increased strength [6,7], higher mobility [3,4,5] and etc. This allows the wearer to perform difficult and repetitive tasks that would otherwise require other additional resources in order to perform. One of such task could be lifting heavy objects from point A to point B without risking physical injury on the wearer's personal body. Another task could aiding humans with incapability of moving by increasing their mobility using exoskeleton[4,5] or replacing their limbs with a prosthetic arm. One may use humanoid movements to map movements from humans to another exoskeleton to recreate or generate the same humanoid movements as the human[9].

Typically one might want to combine multiple characteristics mentioned above into one single mechanical device. However there are many restrictions or limitations which must be taken into consideration when designing an exoskeleton that can be used commercially or industrial. Some of them are weight-distribution, power-supply, maximal pressure on exoskeleton, joint-movements, maintenance costs and etc... [8]. Example, we do not want the wearer to feel the heavy exoskeleton because the human body can only bear such heavy load for a limited period of time until fatigue becomes an issue. The idea is to create a comfortable exoskeleton for the wearer that neglects such discomfort while providing the benefits.

Here in this paper we will propose creating a lightweight exoskeleton-arm in an attempt to solve the weight-distribution while giving the wearer increased capability to lift heavier objects. This is done by using bio-plastic(PLA) that puts less load on the wearer while maintaining the same flexibility and combined with a DC motor in the joint in the elbow will grant the wearer additional assistance in terms of lifting and comfort with cheap materials.

II. MY IDEA

We created a light frame made of bio-plastic(PLA) which is worn around the arm. This design was created using a computer-aided design(CAD) with a software called Fusion 360. One might notice the designs are similarly to one another as we are looking for practical rather than aesthetic purpose[10, 12]. The exoskeleton design is custom-made to scaled personally to wearer's size in this instance, 167 cm. Using 3D-printing we get our personalized parts for the arm. On our designed frame we have installed a DC-motor on the elbow to act as a joint for the arm. Thus our exoskeleton arm becomes 1 Degree-of-Freedom(DOF). However, our DC-motor rotates one direction(counter-clockwise) which is upwards as this is when the wearer lift and gains additional assist. One could let the motor reverse the other direction by applying a controller or even a transistor to let the current flow through the circuit in opposite direction. DC-motor is connected with an Arduino board. This allows for simple framework that connects the DC-motor and the board. As such we can simply program the DC-motor with ease. The table 1, shows the amount of components for the overall arm.

***Table 1:* Specifications of the Exoskeleton arm**

Length from elbow to wrist	30 cm
Length of wrist	20 cm

DC-motor(5 Volt)	1 quantity
Arduino board	1 quantity
Breadboard	1 quantity
Jumper-wires	4 quantity
Total weight	1.5kg

The CAD-model is dimensioned proportionally to the wearer's size and is displayed as in figure 1 below.

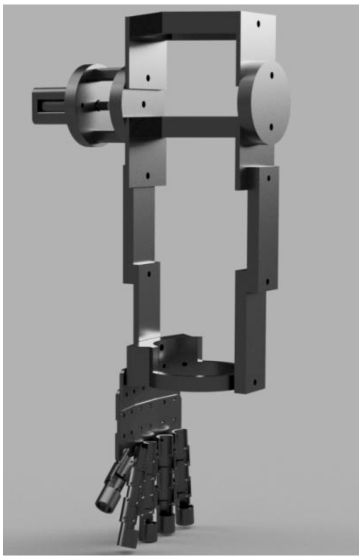

Figure 1: The Exoskeleton Arm

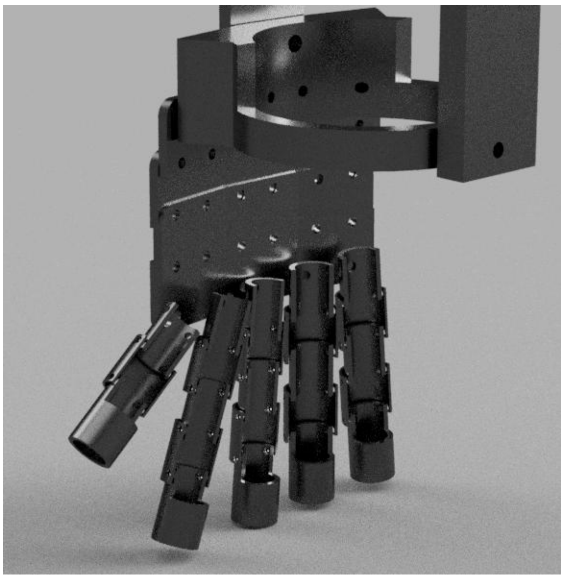

Figure 2: The Exoskeleton arm - Hands

Observing the arm closer, we can notice the fingertips has a ring around them as illustrated on the figure 2 above. This is designed to offer additional protection so that when the user lifts, majority of the pressure will lie on the protected area i.e. the fingertips and not on the wearer's finger. Due to the design of the fingers, it is flexible so the movements are not restricted mechanically and can move with relative ease.

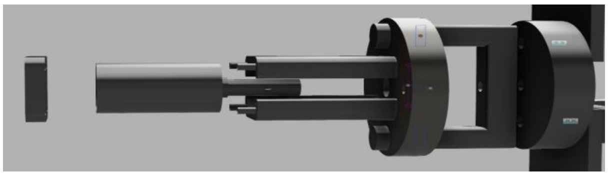

Figure 3: Attaching DC motor to the joint

The DC-motor is the second piece to the left as displayed in figure 3 and will be placed within the four pillars and then closed with a lid. The tip of DC-motor is then connected to the joint and when DC-motor rotate, it rotates the disk and cause the entire joint to rotate accordingly. This DC-motor is however quite small and does not grant the wearer to lift very heavy objects, but rather assists to ease the load on the arm.

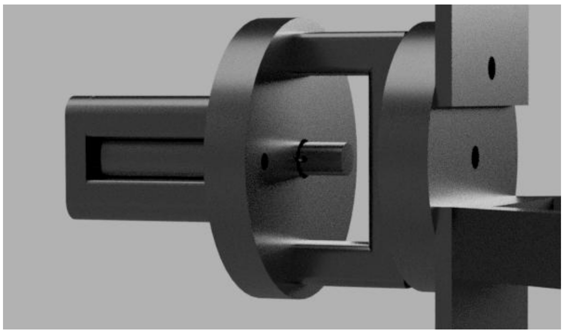

Figure 4: Attached DC-motor on the elbow

Figure 4 displays the finished process of the locked in place DC-motor with the lid on. It does not display the screws or illustration of rotation.

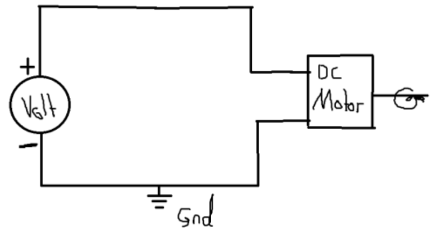

Figure 5: Electric circuit with DC-motor

The electric circuit including Arduino board where Arduino provides a 5 Voltage output for the DC motor. Currently the DC-motor only rotates one direction as the poles remain the same as displayed in figure 5.

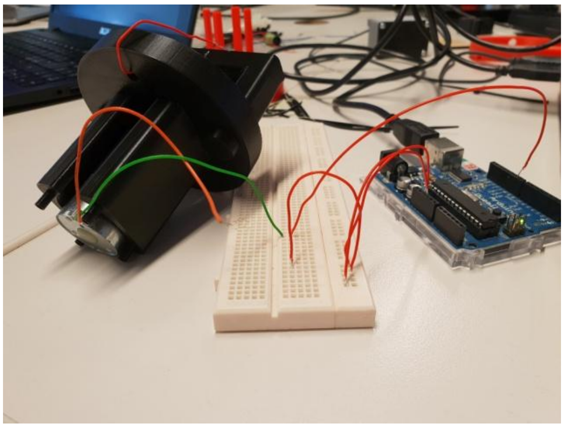

Figure 6: Electrical circuit consisting DC-motor and Arduino board.

On figure 6 above displays the visualization of the circuit. Connecting this circuit as our joint in the elbow will then look as displayed in figure 7.

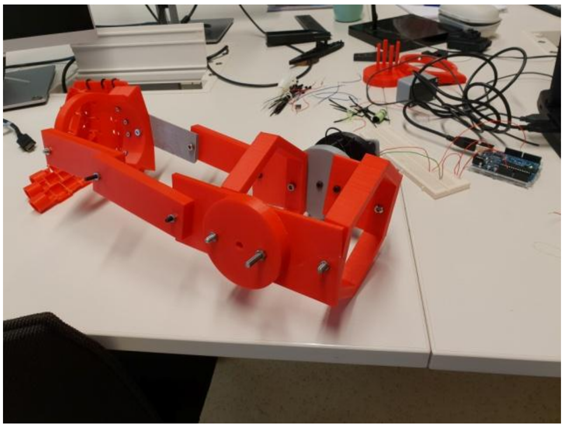

Figure** 7**: The arm assembled with visible circuit

Wearing the arm as displayed above in figure 8 with adjustable link made the arm convenient and flexible. The length proved to be longer than the measured, but this problem was quickly neglected by managing to adjust the different parts. On quantitative analysis the wearer felt the lightweight of the arm, resulting in a comfortable use as the entire arm only weights approximately 1.5kg as displayed in table 1.

However the DC-motor in the joint did not yield enough power outage to rotate the elbow. The entire frame's weight exceeded far greater than the lifting capacity of the DC-motor. What this means is once the DC-motor gets locked, it instead starts to rotate its own body rather than the arm. Due to the design of the arm, one can easily substitute the joint, the black piece, on the right on figure 7 with another and more powerful DC-motor.

Figure 8: Wearing the Exoskeleton Arm

III. RELATED WORKS

Designing an exoskeleton arm has long since been thought off even reaching as far back as in 1967 with the Hardiman Exoskeleton developed by Ralph Mosher[11]. He developed several control systems to allow for human-like action that mimics an operator's natural motion using exoskeleton arms.

Mr. Dasheek Naidu developed in 2011 a 7-DOF Exoskeleton arm reaching from the hand to the human shoulder. The goal is to assist disabled individuals who have lost their motor functions in their upper limb[10].

Recent state-of-the-art exoskeletons are being developed by different universities for support of rehabilitation process after hand injuries or a stroke[13].

IV. FUTURE WORKS

There are multiple ways to improve upon the design as our design is far from perfect compared to the state-of-the-art exoskeleton arms. One might add extra DC-motors on separate joints to allow for additional lifting capabilities. Another advantage to such extra implementation is that we can let the DC-motors hold or maintain a locked position with programming. This means the joints will be locked and all of the lifting is now dispersed over the external frame and not on the wearer. Such dynamic control could be useful for industrial environment.

Since the fingers provide protection, we could install force-sensors on the fingers to register the force. Idea behind is that once the force exceeds certain value or threshold, the DC-motor automatically becomes active instead of manually activating the DC-motors themselves. Simultaneously one could add small DC-motors or pneumatic motor for every finger-joints as in the state-of-the-art *Berlin University Hand and Pittsburgh University* [13]. Comparing our results with them, one could notice that our design is flexible, but *lacks* the extra motor operations. One must take into consideration for a single increase in DOF, means extra calculation and simulation.

The last improvement we will suggest in this paper is creating additional external human-like arm encasing on top of our existing frame. In its current state, the external frame is bulky and not convenient for the wearer to apply it for actual practical exercises as the hindrance is far too great. Removing such constraint of the arm is important for further use, should one choose to divert from the experimentation phase to practical phase. Creating functional mechanic human-like arm could in the future substitute or become an alternative to prosthetic limbs[14].

V. CONCLUSION

In this paper we have created a lightweight Exoskeleton arm that has been rapidly made for experimentation purposes and improved upon. Using cheap materials and 3D-printing, one can design a personalized exoskeleton arm while maintaining a cheap maintenance cost of the arm. By utilizing the basic concepts of exoskeleton arm, one can create exoskeleton arms for different purposes depending on the specifications of said purpose. In our case, the said purpose is prototype arm for further expansion.

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