Body-powered mechanisms for affordable 3D-printed arm prostheses

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Summary

This research focuses on enhancing body-powered mechanisms in affordable 3D-printed arm prostheses for transradial amputees. A novel harness system enables independent grasping actuation, while a wrist rotation mechanism controlled by the healthy elbow improves flexibility. The developed prosthesis demonstrated improved functionality in Cybathlon 2024 tests, reducing the need for compensatory torso movements.

Introduction

The popularization of 3D-printing technology has facilitated the advancement of affordable prosthetic hands enabling customization and self-manufacture under the premise of do-it-yourself (DIY) [1]. Their low cost increases accessibility to developing countries, low-income people and growing children, as demonstrated by initiatives such as Enabling the Future. Early affordable designs were body-powered and their actuator depends on the user's amputation level and mainly these prostheses are controlled by flexing the wrist, flexing the elbow and through the use of a shoulder harness [1]. DIY has also taken advantage of the latest open-source developments to accomplish electric prostheses, like the Arduino microcontrollers, together with compact DC motors and compact batteries. Both types of actuation (body-powered and myoelectric) still need to be improved to achieve optimal functional results. These devices may perform multiple tasks but their fingers bend together and users have difficulty grasping the object as tightly as possible [2,3]. The aim of this work is to improve the body-powered mechanisms of affordable 3D-printed arm prostheses for transradial amputees.

Methods

Actuation of body-powered upper limb prostheses is typically achieved with the extension of the residual limb in relation to the opposite shoulder using a shoulder harness. This limits the grasping ability of the prosthesis in hard to reach places or awkward positions. This is aggravated by the fact that it is uncommon for low-cost prostheses to include rotation between the terminal device and the socket at the wrist, forcing the user to make compensatory movements. New mechanisms were developed to solve the aforementioned problems. The devices were designed using CAD (Solidworks), manufactured with an FDM 3D-printer and assembled using off-the-shelf materials. Finally, these devices were tested with a complete arm prosthesis performing the Arm Prosthesis Race of Cybathlon 2024 tests.

Results and Discussion

The developed body-powered mechanisms are:

1) An harness for the grasping actuation that works via the protraction of the shoulders, and is coupled to the terminal device via a bowden cable, allowing the terminal device to close in any position in relation to the position of the user.

2) The wrist rotation mechanism coupled to a left elbow harness allows the user to rotate the terminal device for 112.5º at the wrist, with 90º of rotation of the elbow. The mechanism works via two pulleys, one on the elbow harness and another on the socket, connected with bowden cables, allowing for a 1 to 1 movement. The pulley on the socket is connected to the base of the terminal device with a 90 degree 20/16 gear transmission.

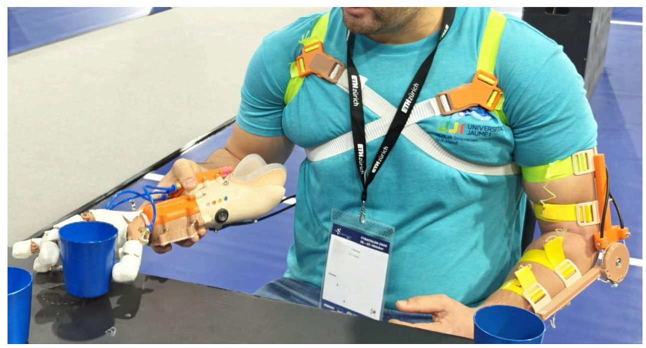

Figure 1: Arm prosthesis with body-powered mechanisms.

The bespoke harness of the developed prosthesis allows for the closening an rotation of the terminal device. The bowden-tube construction allows for the user input to be independent of the position of the terminal device in the 3D space, improving the grasping ability of the prosthesis in hard to reach positions. The input of the wrist rotation mechanism being the healthy elbow is effective, although cumbersome and limits the use of the healthy hand.

Conclusions

The body-powered mechanisms have notably improved the functionality of the 3D-printed prosthesis developed when performing some of the Cybathlon 2024 tests for which wrist rotation or arm extension was required prior to grasping, avoiding torso compensatory movements.

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