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PROCESSING AND VISUALIZATION OF DIAGNOSTIC DATA FROM A BIONIC UPPER LIMB PROSTHESIS

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Abstract

Bionic prostheses are commonly used to help patients perform everyday tasks more efficiently. They incorporate various methods to obtain input from the user and use electric motors to control fingers and/or other parts of the limb. Unfortunately, the rejection rates are averaging 44% [1], meaning almost half of the patients stop using the prosthesis and put it away. The Z-Arm prosthesis from company Z-Bionics attempts to tackle the low acceptance rate by logging diagnostic data and helping the patient when improper usage or possible prosthesis defect is detected. However, since patient visits are not often enough to provide engineers with recent diagnostics, a remote way of obtaining them must be designed. A mobile application utilizing Bluetooth to communicate with the prosthesis has been implemented as a solution. An extension of an internal web application with new pages, API endpoints, and a MongoDB database accompanies it. While the testing is still ongoing and results are yet to be measured, first impressions of staff and patients are positive, indicating a possible improvement in the comfort of prosthesis usage.

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1. Introduction

Limb amputation has a severe impact on everyday life, far beyond what most of us imagine. Apart from congenital defects, amputations are primarily performed after a traumatic injury, such as an industrial or traffic accident [2]. Prostheses have been used to make the lives of amputees easier for centuries, with the first known prosthesis dating back to the 3rd Century BC [3]. While the development of prostheses has been overwhelming, especially after the 1st and 2nd World Wars, the rejection rate (meaning that the patient stops using the prosthesis) is notably low, averaging a staggering 44%.

Z-Bionics, a Czech start-up that specializes in custom-made bionic prostheses, is working on ways to lower the rejection rates, and one of the routes to achieve that is to detect issues with prostheses or their usage before they result in the patient putting the prosthesis away and never using it again. That is why Z-Arm, an upper limb prosthesis, features diagnostic data collection.

Unfortunately, since patient visits occur once a few months, obtaining the diagnostics only during them is far from ideal. Hence, a remote way of obtaining them must be designed and implemented.

This has been achieved by making a mobile application that retrieves the diagnostics from the prosthesis and sends it to our API. The processed diagnostics are then stored in a dedicated time-series database and visualized using the internal website Z-Bionics Hub.

2. Initial research

Multiple solutions were considered when choosing the best way of remotely obtaining the diagnostics. They included adding an IoT module on the prosthesis' PCB or using a Smart USB-C charger connected to patients' home Wi-Fi. The mobile application was eventually chosen because it didn't require making hardware changes to the prosthesis or developing new hardware, such as the smart charger. The mobile application could also be used for other functions, such as configuring the prosthesis.

Another topic of interest was the API to which the application would submit the diagnostics. As we

already had our internal application, Z-Bionics Hub, that we have mainly used to track inventory, we have decided to implement additional functionality into it to support handling the diagnostics, and the same went for the visualization.

3. Implementation

The mobile application uses .NET MAUI, a multi-platform C# framework. The Bluetooth communication incorporates CBOR to reduce the size of messages. The connection is currently insecure because of the lack of support from the firmware, however, a challenge-based OTP is planned for authentication.

Apart from collecting diagnostics, the application can also configure the prosthesis. Currently most used function is the grip configuration, displayed in Figure 4. The prosthesis features three grip modes that can be easily switched between either using a button on the prosthesis or via the application. Furthermore, the application allows for creating personal presets and quickly assigning them to the grip modes.

The API endpoints are secured using JSON Web Tokens and can be used to upload diagnostics to the database. The web application then displays various charts based on the diagnostics.

4. Testing

The ongoing testing includes a patient who regularly uses their prosthesis and Z-Bionics staff who use the Z-Bionics Hub to monitor the prosthesis. More patients are expected to join the testing as new prostheses are manufactured. The testing phase is expected to take multiple months before obtained data can be used, for example, to improve the prosthesis and hopefully reduce the rejection rate.

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