Surveying the Art: Myoelectric Prosthetics

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Abstract

This work aims to survey the state of the art of myoelectric prosthetics. First, we consider myoelectric prosthetics in the context of the peer prosthetic technologies, considering relative advantages and disadvantages. Further, we investigate the methods by which motor neurons signals map to prosthetic movement, specifically targeted muscle reinnervation and mode switching implementations for users with significant amputation.

Introduction

There are many different types of prosthetics which can help to restore functionality to an individual with an amputated limb. Some are simple, like a mechanical arm with a thumb controllable by a cable which the user attaches to some other body part.[1] Other prosthetics may be controlled with buttons, but this has the disadvantage that one arm must be used to interact with the interface which controls the prosthetic limb. Both require the user to move an existing body part in order to control and manipulate their new artificial limb. Myoelectric prosthetics, on the other hand, do not impose this constraint. Myoelectric prosthetics can automatically determine the desired motion by reading electrical activity from a subject's motor neurons by applying an electrode to the surface of the user's skin. This permits the user to control their artificial limb in an intuitive and convenient way. Additionally, research suggests that amputees who use myoelectric prostheses can experience less phantom limb pain[4] - a phenomenon in which residual nerves continue to fire to signal pain[3] in a nonexistent region of the individual's body.

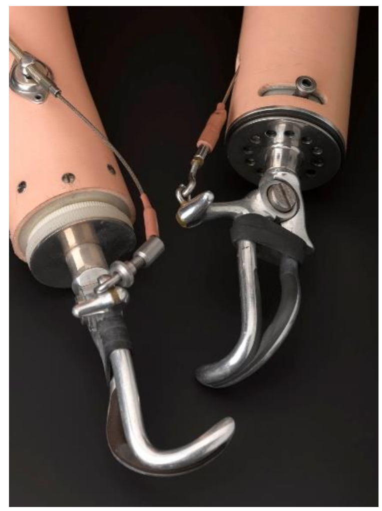

Figure 1[7]: A prosthetic wrist controlled by a cable. In the pictured model, the cables are controlled by a pneumatic system, though in many designs, these cables would be connected to the user's back or shoulders for manual control.

However, myoelectric prosthetics do have drawbacks.[2] As they are electrically powered, the user must carry around a heavy and cumbersome battery wherever they go, and the physical energy required to carry around this heavy battery results in many users abandoning their prosthetic.

Mapping Neurons to Movements

If the muscle whose functionality we wish to restore is *completely* absent, we must arrive at some other method to measure the necessary surface electromyography (sEMG) signals to control a prosthetic device. One method of accomplishing this is a technique called *targeted muscle reinnervation*, or TMR. Many muscle groups consist of several anatomically-distinct muscle heads which are commanded by a common motor neuron; only one such head is necessary for normal function. TMR surgically disconnects and repurposes one of these muscle heads to "amplify" electrical signals.[6] The other head is left alone and continues to provide its own normal function. TMR has drawbacks: unlike other methods discussed, TMR requires an invasive procedure. Further, the subject is now left with fewer functional and connected muscle heads, meaning that they will become weaker in the limb in which TMR is performed.[5]

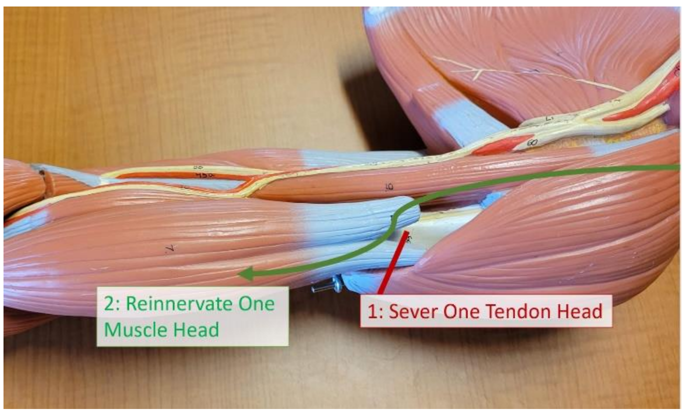

Figure 2:[8] Targeted Muscle Reinnervation. In this example, the biceps heads undergo TMR to control a prosthetic wrist. One bicep head (top) is left as-is to control elbow motion while the other bicep head (bottom) is repurposed. The repurposed bicep head's tendon is severed (detaching it from the elbow), and the nerve controlling the absent degree of freedom (e.g. wrist muscle) is surgically connected (or reinnervated) to the disconnected bicep. An electrode is placed atop the bottom bicep head, and this electrode controls the wrist muscle.

In other scenarios, a user may have many amputated muscles that they wish to control. For example, a user with an upper-limb amputation may wish to control multiple degrees of freedom at the wrist independently of one another. If no portion of any wrist muscles remain, the user will have to leverage their existing, intact muscles to control the wrist prosthetic. If the number of remaining muscles is not large, then a method called *Mode Switching* may be employed, where an antagonistic pair of muscles (a pair of muscles that oppose one another, such as the biceps and triceps) can control a large number of degrees of freedom. Each degree of freedom is considered a "mode" -- within each mode, the two muscles used for control (e.g. biceps and triceps) correspond to the two directions of motion possible within the given degree of freedom. If both controlling muscles of the antagonistic pair are contracted simultaneously, however, the "mode" switches -- that is, the degree of freedom under control changes. As an example, a user with a mode-switching prosthetic may contract their biceps and triceps simultaneously to switch through the available modes (e.g. wrist pronation/supination, wrist radial/ulnar deviation, etc.). Once the desired mode is selected, the user may use their biceps *or* triceps to choose the direction of travel along the degree of freedom. This method can control multiple degrees of freedom from two muscles, but it cannot do so simultaneously -- only one degree of freedom is selected at a time. This is a significant drawback.[5]

Conclusion

Myoelectric prosthetics have some advantages and some disadvantages over peer technologies. As every amputee has a different amputation and different needs, this category of prosthetics has several adaptations to interface with many different types of users. With more time for research and development, myoelectric prosthetics may become easier, lighter, cheaper, faster, and more reliable in the years to come.

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