

Visualizing Physical Therapy with Electroluminescence Wire

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Abstract

Physical therapists have limited ways of assessing whether patients are undergoing treatment regularly and correctly. Likewise, patients undergoing physical therapy have limited ability to assess the accuracy of their exercises. We are developing a wearable electronic device that will provide an indication of rehabilitation progress and accuracy through an ambient visual display to remedy these problems. Therapy patients will be able to visualize their exercises and therapists can monitor the accuracy and regularity of their patients' home exercise programs. This feedback loop can lead to patients that are more likely to adhere to the treatment plan thereby facilitating recovery.

Introduction

Physical therapy exercises are crucial for rehabilitation for patients who recently underwent surgery or suffer from physical impairments. Patients must perform exercises regularly and correctly with the assistance of a therapist to regain mobility and strength. While the patient is instructed on proper form and movement in the rehabilitation clinic, when practicing at home, the patient has little feedback on the correctness and extent of their movements. Moreover, the therapist has no accurate way of checking if the patient is doing the exercises regularly and correctly.

An obvious solution to the problem is to use a simple paper based system where the patient tracks the exercises manually. This paper based solution provides little feedback as to the accuracy of the exercises and is prone to error since the patient is required to manually keep count. While a completely mechanical solution¹ encourages proper movement, it still requires extra work on part of the user to track the exercises. In both of these systems, the physical therapist relies on the patient to inform them as to their progress. From the perspective of the physical therapist, there has been significant research into the use of wearable sensors to monitor therapy; however, most of these solutions have been towards classifying movement², motion analysis³, or measuring physical activity in a target population⁴. While there has been some research into interactive^{5,6} methods, few have combined the requirements of both the therapist and patient⁷. The most notable, Thera-Network⁷ – a smart medical wearable device designed for patients recovering from various types of knee pain – hastens the healing process through distant monitoring and better patient-therapist communication. This device however, is focused more on the question of motivation and addresses the issue through an online buddy network.

In our solution, we do not directly address the issue of motivation, but instead focus more on tracking and presenting exercise form, progress, and accuracy in a holistic way for both the patient and the therapist. We aim to accomplish this through a wearable physical therapy prototype for the elbow with an electroluminescent (EL) wire display, shown in Figure 1 that will provide an indication of exercise progress and accuracy during the path to recovery.

Wearable Electroluminescent Physical Therapy Device

This project is part of a larger human computer interaction and craft technology inspired project where eventually, the device will be tested through user studies with therapists and patients. The EL wire will be used to help provide a visual display to the therapist and the patient on the correctness and the extent of the movement. To accomplish this, a flex sensor will be used to measure the amount of work the patient is doing. The degree of flex can be changed overtime with a simple interface to provide the therapist with the ability to adjust the sensor threshold. We envision a scenario where a patient, who is just beginning therapy, may only be able to flex a small amount requiring the EL wire to light up with lower sensor values. As the patient continues their therapy independently, he will gain more flexibility and thus the EL wire will progressively need a higher value from the flex sensor. Not only does this serve as a visual indicator of progress, but also allows both the patient and the therapist to set achievable goals for recovery.

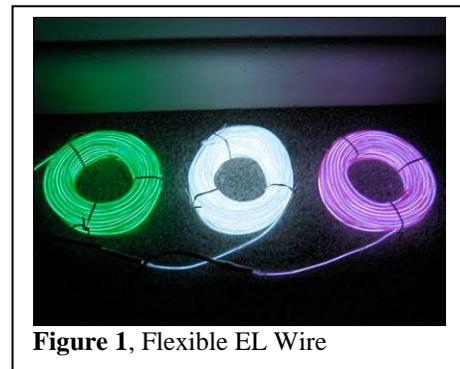


Figure 1, Flexible EL Wire

Design

A design of the prototype is shown in Figure 2. Explanations of the numbered labels in the figure are given below:

1. The EL wire display is a bar graph to represent progress and range of motion.
2. A semi-rigid elbow pad aids in placement of the elbow.
3. The range of motion that this device would initially monitor.
4. Flex sensors in this area would measure arm motion.
5. USB port to provide therapists the ability to download data at each appointment thereby monitoring the patient's activity log. Potentially, this port could also be used for the physical therapist to input data into the device (e.g., number of repetitions).
6. Buttons that turn the device on and off and programming functions.
7. Power source (batteries).
8. Wiring and electronic components will be placed in between textiles so that it cannot be seen on the outside, but also so that the user is comfortable wearing the product.
9. Velcro opening so it is easy to put on.

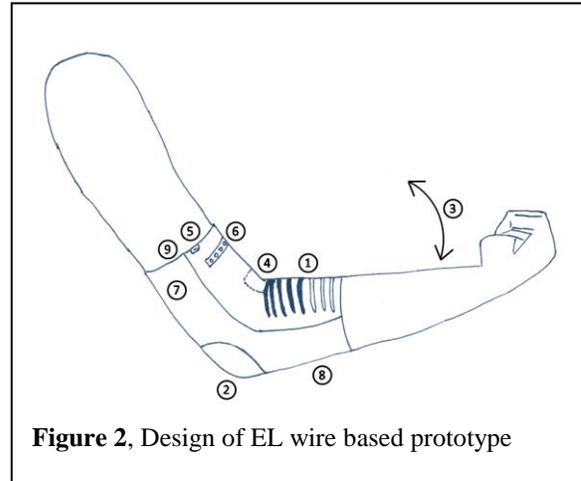


Figure 2, Design of EL wire based prototype

Preliminary Work

In working with EL wire (Figure 1), we have discovered that it is ideally suited for wearable applications. Not only is it low power, it is cool to the touch and is lightweight and flexible, providing us the ability to easily sew it to clothing. Moreover, it is available in a variety of colors that can be used in unison as a visual progress indicator. Unlike traditional LEDs, which require separate connections for each LED, a single one meter strand of EL wire can be weaved through clothing as a single piece making it an ideal choice for wearable applications.

Research Questions to be Addressed

We will address the following research questions:

- *How best should activity and progress be visualized using EL wire?* While Figure 2 shows one potential design for representing information with EL wire, we will explore other interface designs. A key challenge is how we will design an interface that serves both the patient and the therapist. For the patient, the EL wire needs to serve as a visual indicator of proper exercise form, whereas for the therapist it needs to indicate programmed goals. The use of different color EL wire might prove useful in addressing this research question.
- *How will the device be programmed to set goals by the therapist?* The device needs to be easily programmed by users who have no programming experience. The physical therapist in this case needs to be able to modify the flex sensor threshold as the patient's mobility and strength recovers. The programming interface will need to be simple while providing the desired functionality. We will investigate how different electronic components can be used effectively for programming. The challenge here is in preventing the patient from inadvertently programming the device during its usage. We also need to address how best to use the EL wire as a display for this purpose, thus complementing the first research question.
- *How will the electronics and the wearable material be seamlessly integrated so it is easily useable?* Since the user interface here is tangible, we need to integrate the electronics with the wearable material so that it is compact and causes no discomfort to the user. Also since the product is for patients who have limited

range of motion, it must be designed so it is easy to wear. Ideally, the user should not be aware that electronics are embedded as part of the device. We will investigate wearable materials that are flexible and design the enclosure so it is well padded for comfort. Additionally, the electronics need to be compact, and minimal while providing the necessary functionality.

Methods

The research challenges above will be addressed through an iterative design methodology, consisting of smaller design-develop-evaluate cycles for the electronics and the wearable enclosure. While designing the prototype, we will consult physical therapists to understand requirements for accurate elbow movements and the data necessary to monitor a patient's progress. We will also conduct background research on understanding the needs of physical therapy patients recovering from elbow injuries. Specifically, we will explore what visualizations through EL wire are most beneficial to the patient for therapy.

Anticipated Results and Limitations

This work has the potential to satisfy the needs of two user groups - physical therapists and patients. Ideally, physical therapists may use this technology to track patients' progress and help them recover faster with more accurate exercises. This is accomplished by helping the patient visualize the proper movement and accuracy of the exercise. Since research has shown that goal setting aids in motivation for health related tasks⁸, the feedback can lead to better patient-therapist communication and in turn allow both to set achievable goals for recovery. This device may also help therapists better understand how patients recover and what problems they may come across as they exercise their arm with the device, thus enabling therapists to better treat a patient's needs.

An unintended consequence of this research deals with the privacy of the patient. While we assume that the patient wants to share her progress with the therapist, the patient may be uncomfortable with the device keeping records of her exercise. If for example, she has not performed the required count for the day or the week, she might not necessarily want to discuss the issue with the therapist to avoid discomfort. The device however, is transparent and informs the therapist of all activity or lack thereof.

This work brings together ambient displays from HCI to create a wearable device that enhances existing physical therapy technology. While how to capture and present activity and progress have been well researched through standard screen-based interfaces in HCI, we are extending research in wearable interfaces through an EL wire display. Essentially, our research creates a wearable interface that can display, count, log, and disseminate information to both patients and health care practitioners. These functionalities can be used in countless wearable applications - from a wrist band that tracks smoke for smokers trying to quit to a belt that tracks physical activity - that health informaticians can use in their own research.

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