CHAPTER 11
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KNEE REHABILITATION PROJECT

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INTRODUCTION

Knee connective tissue rehabilitation involves splinting the knee and providing static stretching in a controlled manner to maintain and extend range of motion after corrective surgery. The patient leaves the operation with the ability to bend the knee to 90 degrees. The objective of the post-operative therapy is to maintain this deflection and extend it to 110 degrees.

There are commercial products that perform this function; however, they do not have automated sensing and monitoring capabilities. The goal of this design project is to create a prototype system that prevents the user from executing motion that damages the repair while providing the force necessary to obtain the desired deflection, up to 110 degrees. The force is to be provided over specified time intervals. The device senses the applied force and provides monitoring capability. The force is limited to a maximum allowable value.

SUMMARY OF IMPACT

Every year, nearly 300,000 patients in the United States undergo knee replacement surgery. Following this surgery, a patient's range of motion (ROM) in the affected joint is significantly reduced. One of the most important factors in regaining ROM after such a surgery is an aggressive rehabilitation program. In daily living, a person requires roughly 67 degrees of knee flexion to walk, 93 degrees to rise from a chair, and 125 to kneel in prayer. Through controlled stretching of the joint, gradually increasing the tension of the connective tissue in the knee, a patient can regain near pre-operative range of motion.

TECHNICAL DESCRIPTION

The knee rehabilitation system includes a mechanical device to assist in static-progressive stretch therapy, and sensors to record the time and duration of use, as well as the applied force and the flexion angle achieved by the user.

Fig. 11.1. Knee rehab device.

Operation of the system is accomplished through the use of a lead screw to translate the patient's foot along a track. The motion of the lead screw is entirely controlled by the patient using a hand crank. This high level of patient control lowers the incidence of muscle guarding, which in turn leads to a more successful rehabilitation program. Data collection is completely autonomous, which allows the system to function as a compliance device, and also makes the device useable and accessible to the target user, a geriatric total knee replacement patient.

The patient is expected to use the device for 30 minutes three times per day during the course of the rehabilitation program. When the hand crank is rotated clockwise, the lead screw causes the pedal mechanism to move towards the patient's body, thus putting the knee in flexion. Extension is accomplished by reversing the direction of the crank. As the patient is expected to be exercising at the extremes of their range of motion, the pedal mechanism can be disconnected from the lead screw to quickly move from one extreme to the other, while allowing finely incremented motion when engaged. Load cells mounted on the pedal mechanism record excessive forces, which are indicative of muscle guarding. Tilt sensors mounted on the patient's leg record the angle of the knee, and a timer on the tilt sensor records the duration of use. When the foot is removed from the pedal at the conclusion of the therapy session, the collected data is transmitted to the patient's physician through a Tele-Health Home Monitoring system.

The cost of parts/material is approx. $1500.

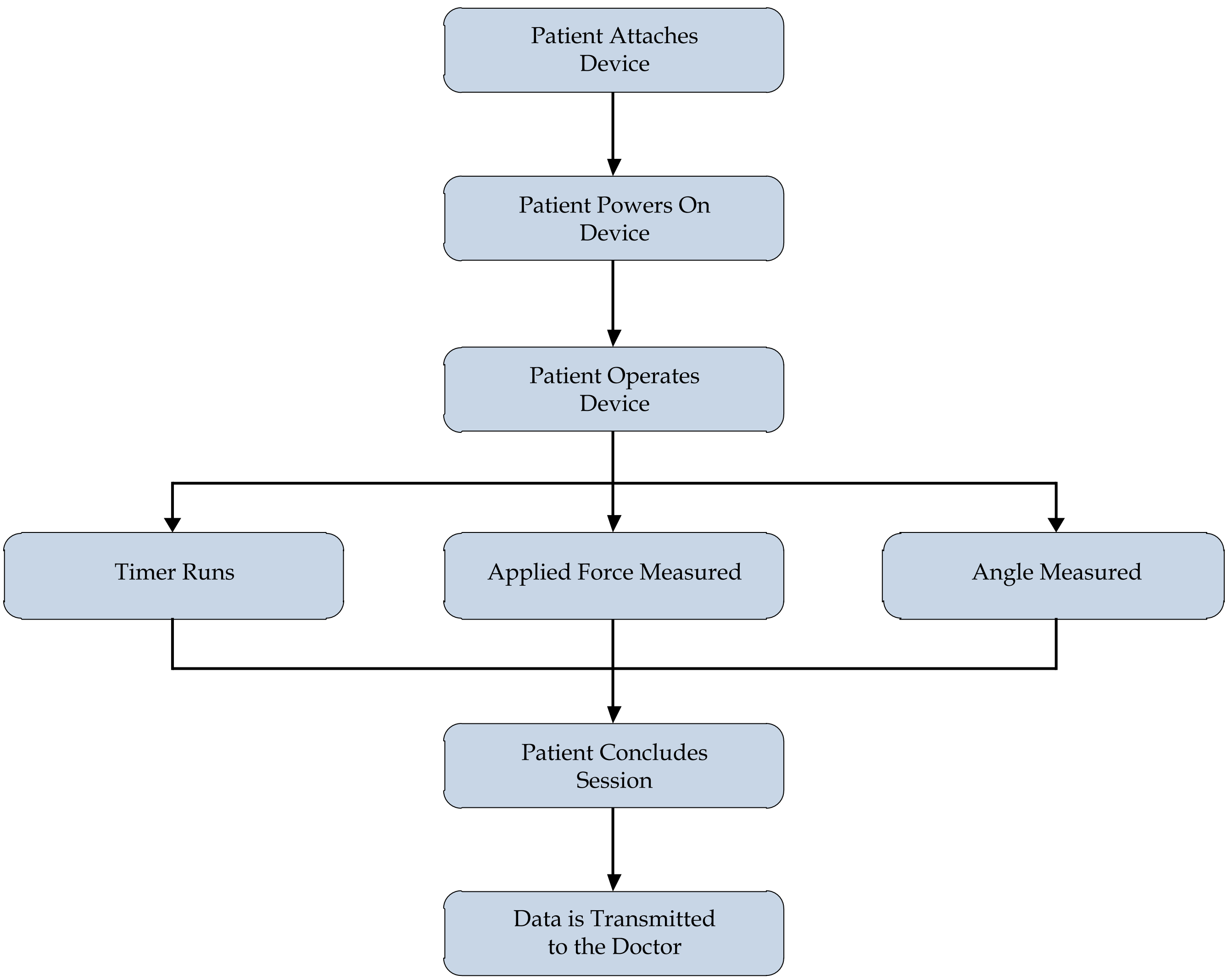

Fig. 11.2. System overview diagram.

WEARABLE MOUSE

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INTRODUCTION

The purpose of the project is to provide access to a computer and assistance to operate a computer for an injured individual with limited motor abilities in some part of their body. A human-computer interface is designed to enable such an individual to operate a computer. The interface simulates the cursor movements and functions of a standard computer mouse by interpreting gestures by the individual. Through a combination of hardware and software interfaces, all basic functionality (e.g. internet and email) of the computer is accessible.

In September 2007 the University of Denver received a project request to develop a computer interface for a patient with systematic nerve damage due to a spinal cord injury. The paralysis was total except for the patient's left arm and from the neck up. In addition the patient had no use of his hands, preventing the use of standard computing interfaces.

SUMMARY OF IMPACT

From the University of Alabama National Spinal Cord Injury (SCI) Statistical Center – (March 2002): 250,000 Americans are spinal cord injured. 52% of spinal cord injured individuals are considered paraplegic and 47% quadriplegic. Approximately 11,000 new injuries occur each year. SCI injuries are most commonly caused by vehicular accidents (37%), violence (28%), falls (21%), sports-related (6%), and other (8%). The most rapidly increasing cause of injuries is due to violence; vehicular accident injuries are decreasing in number. We can only assume that the number of spinal cord injuries will increase due to the wars in Afghanistan and Iraq.

TECHNICAL DESCRIPTION

The system includes a sensing device and a microprocessor integrated into a wearable human computer interface (Figure 11.4). The sensing device

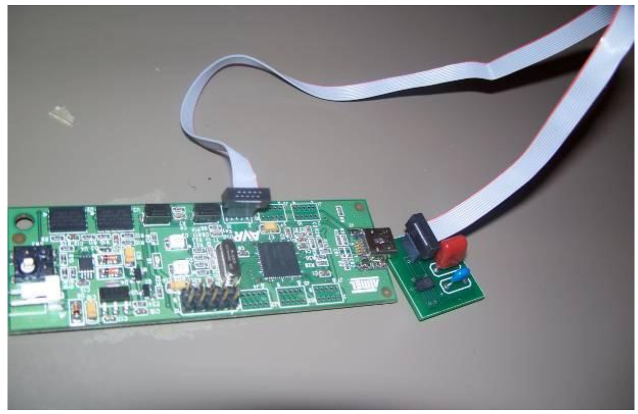

Fig. 11.3. Wearable Mouse Prototype.

is used to monitor the position and/or motion of the user's body part (e.g. arm). The microprocessor provides the interface to the computer system and implements the calculations necessary to interpret sensor data into mouse positioning and click data. The device is implemented on a wearable platform in the style of a wrist-guard. It is attached to the computer with a USB cable and is designed to be used while sitting in front of a computer system. The device is insulated to prevent electrical interference or damage to the components while the device is being used.

The sensor subsystem is an accelerometer. When the user moves, the motion is detected by the accelerometer and converted into cursor/mouse positioning data by the microcontroller (Figure 11.5). This data is sent to the computer over the USB cable. Additionally, the user is able to move in a predefined pattern, or gesture, to initiate a mouse click. The microcontroller interprets this motion as a click and sends the appropriate signal to the computer. The system is calibrated to work for a variety of users, but has methods for re-calibrating to a specific user's needs.

The cost of parts/materials was $128. The weight of the parts/materials was 15 grams.

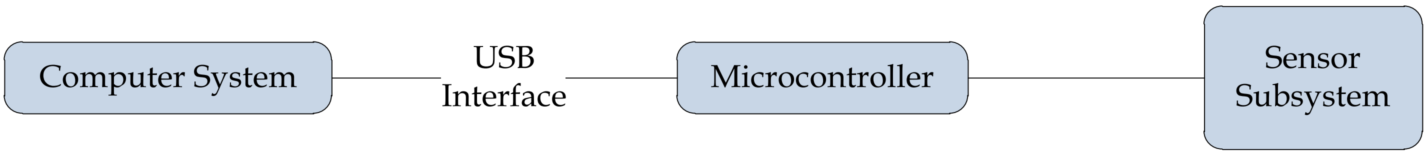

Fig. 12.4. System block diagram.

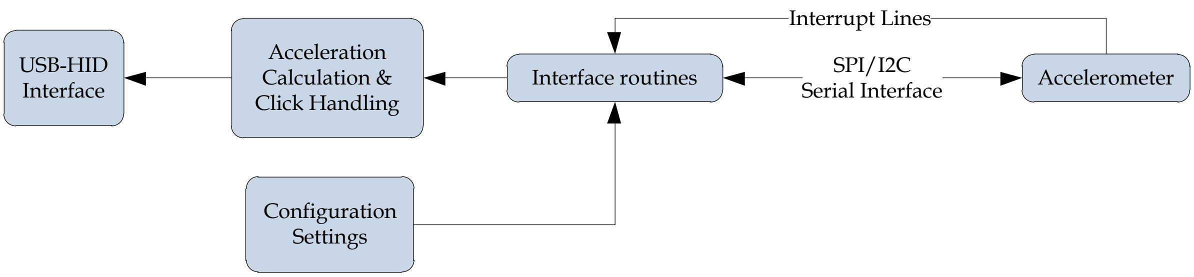

Fig. 11.5. Microcontroller interface diagram.

RECIPROCATING GAIT ORTHOSIS

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INTRODUCTION

The inability for paraplegics to stand and walk cause several physiological complications such as pressure sores, urinary and intestinal stasis, accelerated osteoporosis, edema, spasticity and an increase in cardiovascular risk. To alleviate these problems numerous orthotic devices have been created to provide upright stance, as well as some level of mobility. This project is focused on the reciprocating gait orthosis (RGO).

SUMMARY OF IMPACT

In spite of the rapid evolution in orthotic design, these devices require high energy expenditure with low efficiency of energy to movement. Additionally, many patients complain of the bulk of the design that is difficult to put on and take off without assistance. On average it takes users 8 to 9 minutes to put on the device and 4 to 5 minutes to remove. Though 50 years has passed since the origin of the design, and numerous attempts at improvement, as many as 71% of all patients prescribed the device become non-users within one year.

Additional problems arise due to the costs involved with these devices. Some of these devices can cost as much $10,000 which is largely due to the manufacturing constraints as every device is completely customized to a single patient, eliminating the potential for mass production and economies of scale. Complete customization is also problematic, particularly for children, as height and weight changes of the patient require a completely new system.

TECHNICAL DESCRIPTION

The re-design elevates the position of the rocker bar and reduces the energy requirements for the RGO by 49%. Raising the rocker bar increases the ability to apply greater forces and torque to the mechanism. It utilizes the upper body muscles (shoulders) for rotation, instead of relying on hip abduction. This allows for greater rotation in the sagittal plane.

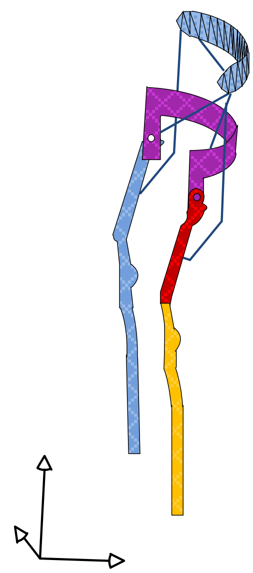

Fig. 11.6. Reciprocating gait orthosis frame.

The undesirable effects produced by raising the rocker bar are counter acted by the advancements of the new design. The same magnitude of rocker bar rotation produces a smaller displacement of the foot. More force needs to be applied to produce the same amount of displacement. This increases the amount of force that the moment arm experiences during gait. However, the increase in ability to generate rocker bar rotation counter-acts this decrease in displacement.

The cost of parts/material was about $500.

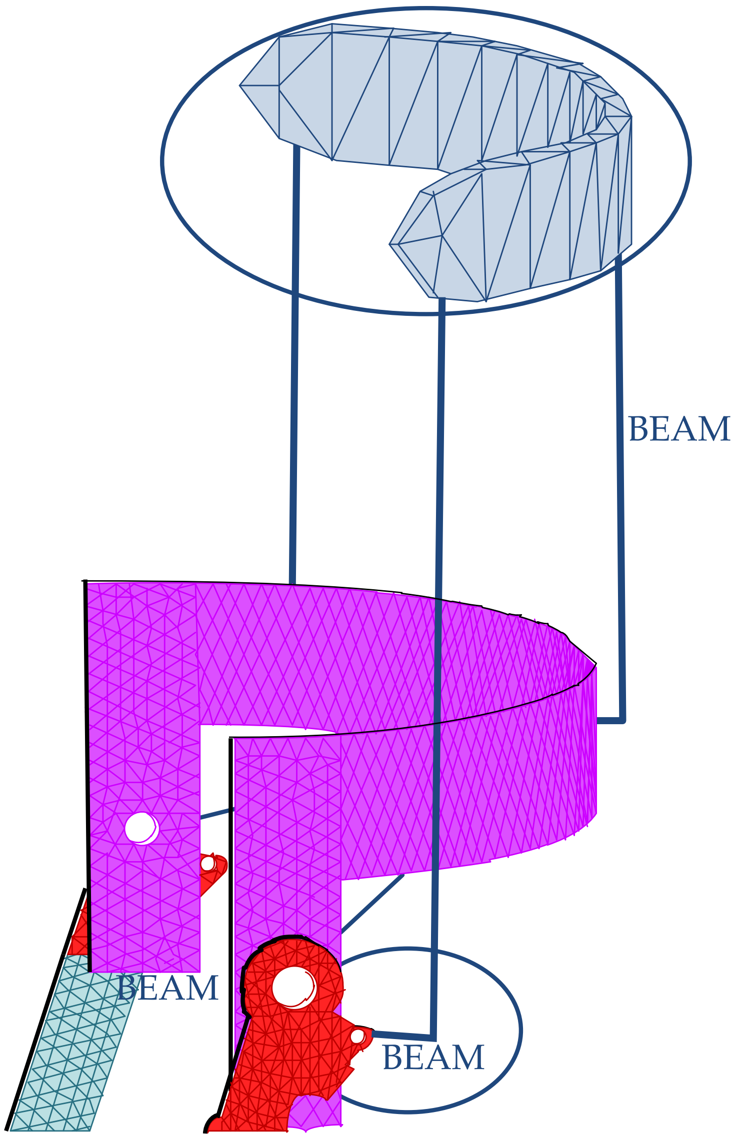

Fig. 11.7. Rocker bar redesign.