Engineering
University at Buffalo The State University of New York
The School of Engineering and Applied Sciences

Mechanical & Aerospace Engineering Department.

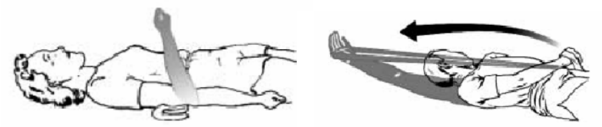
Musculoskeletal Analysis-based Rehabilitation Programs Refinement

Research Goal:

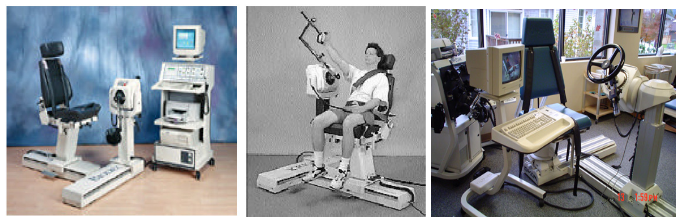
To create a Virtual Design Environment, leveraging tools from musculoskeletal analysis, optimization, simulation-based design, that will permit a therapist to systematically and rapidly evaluate various candidate rehabilitation programs.

Motivation:

- Each year, growing number of people suffer from diminished motor capabilities, due to disease (muscular dystrophy and stroke), aging or simply disuse.
- Physical rehabilitation can help to recover capabilities.



Sample Exercises suggested by National Stroke Association.



Example of Commercial Computerized Exercise Systems.

Challenges:

- Rehabilitation is a multifaceted process with complexity and variability that depends not only on human patients and/or specialized equipment but also on the nature of their functional interaction.
- Rapid and effective customization of the functional interactions between the patient and the rehabilitation device is critical for any rehabilitation program.
- Two principal dimensions that govern the effectiveness of such functional interactions are geometric placement of user-device (ergonomics) and exercise selection and performance (regimen).

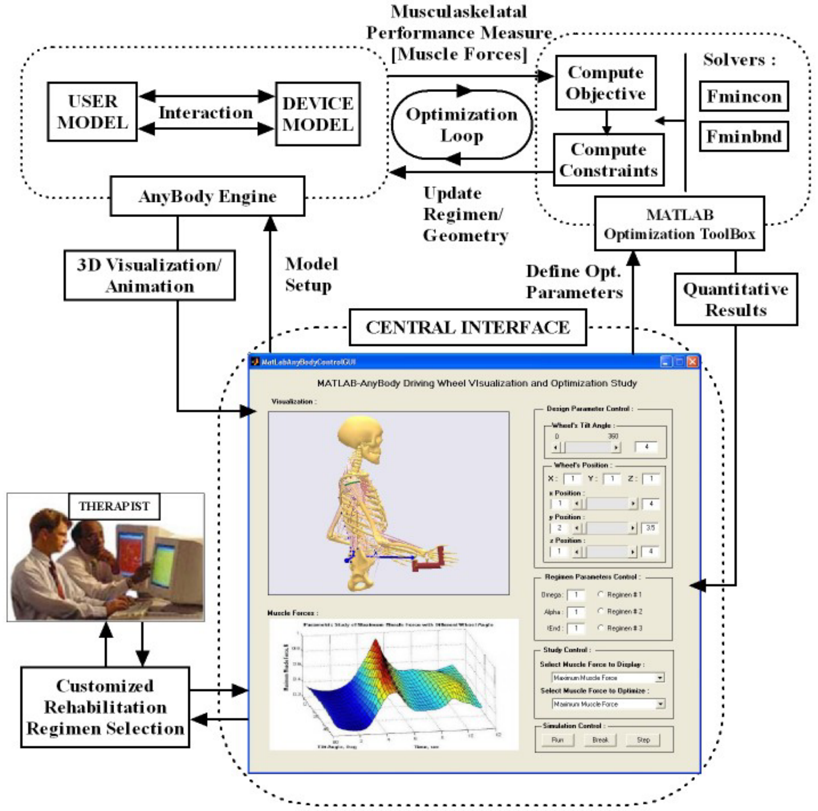
Specific Research Questions:

- How to evaluate the effects of ergonomics & regimen for a rehabilitation program?
- How to refine and customize the rehabilitation program in a systematic way?
- How can a therapist define the appropriate rehabilitation program for a particular patient based on: the patient geometric parameters & rehabilitation progress?

Our Approach:

- Create, test, evaluate and refine rehabilitation regimen by a Virtual Prototyping (VP) methodology that widely used in Engineering Design.
- Perform Simulation-Based Design (SBD) to study and refine the interactions of a patient with the rehabilitation equipment and regimen completely in a virtual environment.
- The integration of engineering support tools, such as musculoskeletal analysis, optimization and structured therapist involvement within a common design environment.

Our Framework:



Paradigm of our framework for VP of rehabilitation device: A MATLAB GUI that serve as the Center Interface that allows the therapist to examine the effects of different regimens and determines the 'best' regimen based on user's geometric informations. The AnyBody engine provides the user/device VR model and responsible for the computation of the muscle forces, while the optimization routine is handle using MATLAB's optimization toolbox.

Case Study:

A motor-rehabilitative **Haptic Virtual Driving Environment** (hVDE). This hVDE was developed by integrating a commercial-of-the-shelf (COTS) force-feedback steering wheel with parameterized rehabilitation therapies to serve as a home-based inexpensive personal-movement-trainer.

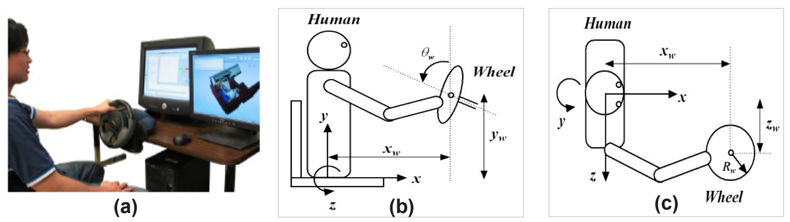


Figure (a) The actual setup that is being modeled and studied; (b) Front view of the user and driving wheel (rehabilitation device) arrangement in the case study; and (c) The corresponding top view of the same arrangement.

Specifically, users are instructed to perform structured-rehabilitation-exercises in the form of driving-tasks along prescribed parametric paths while holding the driving wheel with one- or both-hands.

Two Studies Performed:

(1) Parametric Study; (2) Optimization Study.

Results:

Musculoskeletal Model:

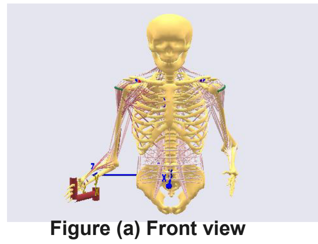


Figure (a) Front view

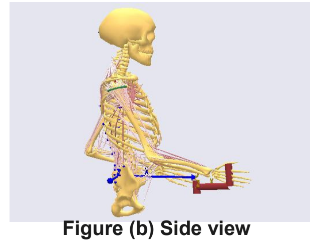


Figure (b) Side view

Results (Parametric Study):

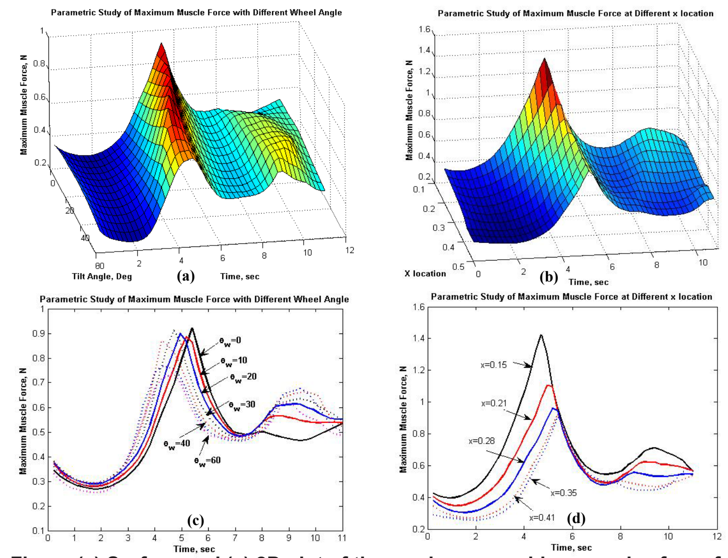


Figure (a) Surface and (c) 2D plot of the maximum combine muscles force for a patient to turn a wheel at a constant angular velocity of 30deg/sec (with 330 deg total movement), for a 0 to 60 degree tilted wheel angle, with wheel center located at (0.25, -0.1, 0.25), measured in meters ; and (b) Surface and (d) 2D plot of the maximum combine doing the same motion, this time with 0 deg tilted angle (no tilt) , for wheel x position varied from 0.1m to 0.45m.

Results (Optimization Study):

$$\min_{x_w,\,\theta_w} \; f_i\left(x_w, \theta_w\right)$$

$$s.t:$$

$$g_1: 0.15 \le x_w \le 0.25$$

$$g_2: 0^\circ \le \theta_w \le 60^\circ$$

Two Objective Functions:
(a) Muscle Force Fluctuation;
(b) Average Muscle Force.

Two Design Variables:
(a) location of wheel, x_w
(b) Wheel tilted angle, θ_w

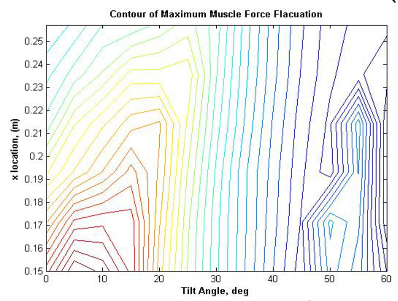


Figure (a) Function space of muscle forces fluctuation

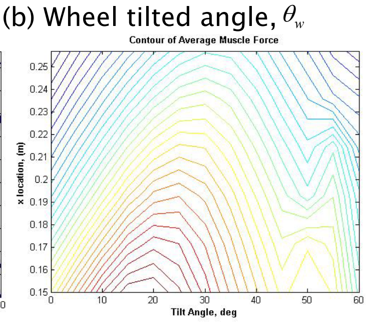


Figure (b) Function space of average muscle force.

Reference:

Lee, L-F., and Krovi, V., "Musculoskeletal Simulation Based Optimization of Rehabilitation Programs," Proceedings of the 2006 IEEE International Workshop on Virtual Rehabilitation, New York, NY, August 29 -30.

Presenter: Leng-Feng Lee
llee3@eng.buffalo.edu
http://www.eng.buffalo.edu/~llee3

Advisor: Dr. Venkat Krovi
vkrovi@eng.buffalo.edu
http://www.eng.buffalo.edu/~vkrovi

Automation, Robotics & Mechatronics Laboratory ARM Lab
http://mechatronics.eng.buffalo.edu