

Virtual Musculoskeletal Analysis-based Refinement of Rehabilitation Programs

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.

Motivations:

- 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.

Specific Research Questions:

- How do we evaluate the effects of ergonomics & regimen for a rehabilitation program?
- How can we 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?

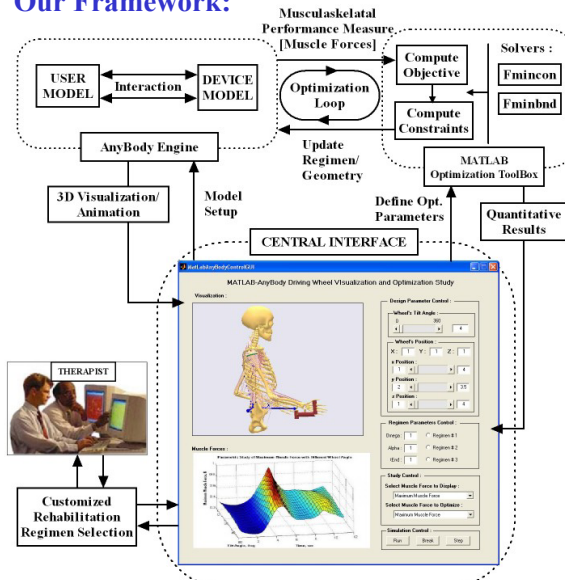
Our Approaches:

- 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.

Challenges:

- Rehabilitation is a complex 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 thus becomes 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)**.

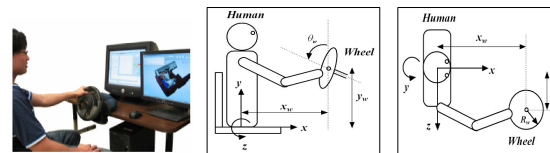
Our Framework:



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



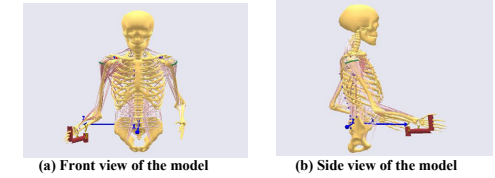
(a) The actual setup that is being modeled and studied; (b) Front view of the user and driving wheel (rehabilitation device) arrangement in the case study; and (c) The corresponding top view of the same arrangement.

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.

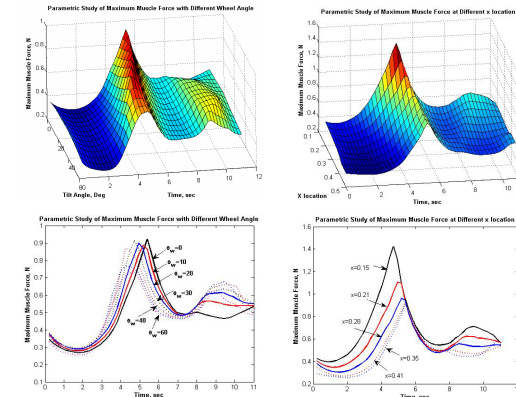
Two Studies performed:

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

Model using AnyBody Musculoskeletal Modeling System:

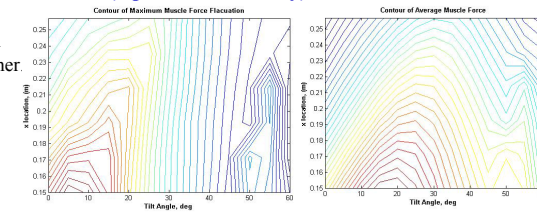


Results (Parametric Study):



(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 (far or close in front of the user).

Results (Optimization Study):



(a) Function space of muscle forces fluctuation (b) Function space of average muscle force.

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

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