ARM SUPPORTS TO WEAR OR NOT TO WEAR?

Design of a Subject-specific Orthosis for Upper Extremity Assistance

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Brachial Plexus Injuries (BPI) caused by trauma, mainly motorcycle accidents, result in paralysis

• Motorcycle accidents involving male subjects (age < 30)
• Injured nerve pathways
• Compromised muscle function

Motivation

• Understanding patient’s level of impairment to assess whether or not a patient can be assisted with a passive orthosis
• Optimizing the orthosis design through human-orthosis simulation to achieve a design with essential components only
• Finding new approaches to aim at a wearable, lightweight and inconspicuous custom-fit orthosis
• Enabling independent and mobile patients at home

Assistance of patients with Brachial Plexus Injuries using an arm orthosis

Musculoskeletal system indeterminacy is solved according to a muscle recruitment criteria

• AnyBody Modeling System (AMS) [AnyBody Technology A/S, Aalborg, DK]
  Human bones rigid bodies/segments
  Human joints joints linking segments

  • Right arm model (10 joints; 134 muscles)
  • Full inverse dynamics analysis

\[
\text{Motion} \quad \Rightarrow \quad \text{Internal Forces} \quad \Rightarrow \quad \text{Minimize} \quad G(\mathbf{M}) = \sum_{i} \left( \frac{m_i}{N} \right)^{1/2} \quad \text{Subject to} \quad C \leq 0, \quad i \in \{1, \ldots, n\}
\]

where \( f = [f^{(a)}, f^{(b)}] \). \( f^a \) and \( f^b \) are muscle forces and joint reactions
Musculoskeletal model is scaled to the patient’s anatomy fitting the motion captured data

How accurate can BPI diagnosis techniques be for predicting muscle atrophy?

“Golden Standard” for biomechanical modeling of patients with BPI: Electromyography!

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Orthosis design choice: a passive device

Acquiring physiognomy data using Microsoft Kinect® 1.0 for a custom-fit orthosis
New orthosis design concept CAD model for co-simulation: custom-fitted braces + bungee cords

- Covers five degrees-of-freedom
  - Shoulder+Acromioclav. joints, 3+1-DOF
  - Elbow flexion, 1-DOF
- Parts:
  - Trunk armor
  - Upper-arm brace
  - Lower-arm brace
- No mechanical joints
- Six bungee cords provide support (elastic potential energy)

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Design case for optimization: motion data of pick and drink from a cup drives the model

Reducing the maximal force required by residual functional muscles over all postures

- Pre-defined 12 mm resting length per each cord
- Mixed-integer nonlinear optimization for number of parallel cords per connection
- 6 design variables: Num. Parallel Cords, NC
- Hand payload of 1 kg (purple ball)
Manufacturing the new orthosis design in ABS

New orthosis design concept using custom-fitted braces and bungee-cords ("plug&use")

Discussion & future developments

• Theoretically, a patient-specific model can simulate the biomechanics of the upper limb with paralysed muscles
• When the level of muscular impairment is complex and individual, the model needs strength scaling and validation
• According to the simulations, an optimised orthosis design assist the patient in some common daily activities
• Design optimization is essential for experimentation and design maturation before the manufacturing stage
• Emerging 3d-printing technologies can enable manufacturing a compact, wearable, affordable inconspicuous orthosis
• Clinical validation of a prototype is mandatory to assess the function of the orthosis under operating conditions

References


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