Development of a Nonmotorized Mechanism for Ankle Rehabilitation

Rogério Sales Gonçalves
Lucas Antônio Oliveira Rodrigues
René Humbert
Giuseppe Carbone
Introduction

Use of robotic structures for rehabilitation:

- Used for different types of treatments
- Reduces costs with active labor
- Allows the execution of new exercises
Introduction

Use of nonmotorized devices:

➢ Easy operation by the end user
➢ No prior training is required
➢ Simple functionality
➢ They are capable of generating positive motivational effects
➢ Patient independence to perform exercises
State-of-the-Art: Structures applied to rehabilitation

Generally, the great cost and complexity of the structures for rehabilitation present in the literature is the presence of actuators associated with complex control systems.
Ankle kinesiology

The main action of the ankle joint is to allow dorsiflexion and plantar flexion of the foot.
Mathematical Model of the Ankle Device

Mechanism developed based on the planar 4-bar mechanism

Considerations:

- Grashof's Law: Crank-rocker mechanism
- Low speeds and accelerations: Static modeling
- Rigid bars
- Backlash and friction in joints not considered
- Only ankle flexion movements
- Mechanism built from the amplitude of Ankle joint
Mathematical Model of the Ankle Device

Use of an evoluzional algorithm optimizer to obtain the lengths of the bars;

- Angular output equal to ankle joint amplitude
- Transmission angle ($\gamma$) between 30° and 150°

\[
\theta_4 = 180^\circ - \lambda - \beta \quad 0 \leq \theta_2 < 180^\circ
\]
\[
\theta_4 = 180^\circ - \lambda + \beta \quad 180^\circ \leq \theta_2 < 360^\circ
\]

The obtained lengths are:
- $r_1 = 273$ mm
- $r_2 = 104$ mm
- $r_3 = 235$ mm
- $r_4 = 164$ mm

\[
s = (r_1^2 + r_2^2 - 2r_1r_2\cos \theta_2)^{1/2}
\]
\[
\beta = \cos^{-1}\left[\frac{(r_3^2 - r_4^2 + s^2)}{(2sr_3)}\right]
\]
\[
\psi = \cos^{-1}\left[\frac{(r_3^2 - r_4^2 + s^2)}{(2sr_3)}\right]
\]
\[
\lambda = \cos^{-1}\left[\frac{(r_4^2 - r_3^2 + s^2)}{(2sr_4)}\right]
\]
\[
\gamma = \pm \cos^{-1}\left[\frac{(r_4^2 - s^2 + r_3^2)}{(2r_3r_4)}\right]
\]
CAD/CAE Simulations and Results

Chain drive mechanism transmission to reduce the patient required effort to a comfortable level
CAD/CAE Simulations and Results

Output amplitude/Angle obtained:

Ankle range: 80°
Obtained: 78.891°
Error: 1.386%
CAD/CAE Simulations and Results

Figure. Sequence of images representing the simulation of motion ankle device.
CAD/CAE Simulations and Results
Conclusions

➢ In this paper, a simple, yet innovative design of a crank-rocker mechanism is proposed, combined with a chain-drive transmission to ankle rehabilitation.

➢ This novel structure offers new possibilities to the rehabilitation scenario while being able to assist motor recovery on both paretic limbs of the patients, simultaneously.

➢ The proposed device was modeled mathematically, and the dimensions were obtained with the aid of an evolitional algorithm.

➢ Static analysis reveals that the structure can be built using light and easy-to-find materials, thus reducing the costs.

➢ The graphical simulations shown that the mobility is compatible to the ankle joint movements, while the crank can explore global movements of the upper limb.

➢ The next step will be construction of the prototype and realize experimental tests with patients.
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Rogério Sales Gonçalves – rsgoncalves@ufu.br
Lucas Antônio Oliveira Rodrigues - lucas.ep@outlook.com
René Humbert - rene.humbert@ens2m.org
Giuseppe Carbone - giuseppe.carbone@unical.it