

Thesis title

Methods of automatic diagnosis of muscular motor strength in the hand, wrist and elbow area and rehabilitation support in occupational therapy.

Abstract

One of the issues related to rehabilitation is the shortage of specialists—neurologists, orthopedists, and physiotherapists with adequate education to effectively assist the large number of patients in need. For example, according to the European Commission, it was estimated that in 2020, there would be a shortage of about 50,000 physiotherapists in the EU.

A solution to the problem is the automation of diagnostic procedures and the support of treatment with rehabilitation robots. However, according to the current state of knowledge, there are no effective tools that aid in the diagnosis of joints whose rehabilitation is supported by machines, and the use of existing diagnostic criteria is associated with a high number of false-negative results (understood as the determination of the inability for effective rehabilitation when it is actually possible). Hypotheses regarding automatic diagnostics can be validated by showing measurable progress in rehabilitation. Therefore, in addition to developed methods of automatic diagnostics using biomedical signals, original equipment was designed and created within this work to support rehabilitation and enable objective measurements of rehabilitation progress.

Currently, the market offers solutions that enable the rehabilitation of major joints; however, most of these are large devices designed to operate at higher torque ranges than necessary for occupational therapy. Devices like System 4 (Biodex), Primus RS (BTE), or Luna EMG (EGZOTech) are primarily dedicated to rehabilitating joints such as the ankle, shoulder, elbow, knee, and hip. Other devices, such as Pinchmeter (Biometrics), can apply continuous variable pressure between fingers but do not fully support functional training and may affect patient motivation. The Upper Limb Exerciser (Biometrics) provides only a constant, manually adjustable resistance on a rotating element, encouraging movement through play but not leading to dynamic training where resistance and machine behavior should vary.

The above mentioned analysis leads to the creation of the primary research objective, which is to develop original methods for the automatic diagnosis of muscle motor strength in the areas of the hand, wrist, and elbow, and to verify their usefulness in occupational therapy rehabilitation. The partial objectives also included the development of a device to increase the motor strength of selected upper limb muscles and a chair to support rehabilitation and diagnostics.

The proposed research project focuses on using electromyographic (EMG) signals to objectify and automate the diagnosis of patients requiring physical rehabilitation. The true value of the developed methods will be verified through exercise scenarios supervised by

physiotherapists, assessing patient progress via parameters such as joint range of motion and EMG signal strength. The project aims to create a diagnostic system and methodology for consistently measuring patient force or range of motion. Current solutions mainly rely on dynamometric measurements (torque, force) and angular rotation (range of motion). For patients with reduced wrist and hand mobility, precise pressure measurement is necessary, whereas most technical solutions only provide one measurement option, either grip force or torque measurement. Additionally, the designed device will use bioelectrical feedback from EMG signals for patients with extremely low muscle mass, initiating movement based on received electrical signals. Therefore, a secondary goal is to develop an effective automated occupational therapy using a small robot designed and built as part of the project, capable of transferring torque across different planes relative to the robot's main axis and conducting exercises mimicking daily activities such as turning a key in a door, screwing/unscrewing a light bulb, pressing and pulling a door handle, and opening/closing a cap. Each training session, conducted in collaboration with a physiotherapist, should address daily mobility needs at home, in the city, or while driving, ultimately aiming to provide the patient with full independence in performing tasks. Precisely defining the execution of each functional training is crucial as it will initially determine the components required for the device to replicate these movements.

Key words

EMG signal analysis and processing, rehabilitation robot, neurorehabilitation, automatic diagnostics