IN.EX.A.: INtelligent EXoskeletal Arm

Maximos Bolotas*, Christina Theochari*, Panos Tsimpos*

Supervisor: Andreas Karampelas†

*Hellenic American Educational Foundation, Athens, Greece, in.ex.teamgr@gmail.com

†Professor of Information and Communication Technology at Athens College, HAEF, akarampelas@haef.gr

1. Introduction

Muscle weakness is a condition that many individuals in the world face. It can either be a result of inheritable myopathies (14% of the world's population), neuropathies or joint/bone surgery. Consequently,, either permanent support or energetic/passive rehabilitation is needed. Both can be achieved in the arm using an exoskeletal apparatus, developed by our team and presented in this paper, which intelligently predicts and mechanically aids the movement of the forearm.

2. Mechanical Design

The system is based on an orthopedic ROM Telescopic Elbow Brace (model *MB.2000* of *Medical Brace*). The brace can be fastened on the forearm and upper arm of a wearer, fitting any lower/upper arm length, as well as any lower/upper arm circumference. The apparatus has been modeled as two axes connected by a hinge joint. A Gear Motor with a Magnetic Encoder is attached on one axis. A perpendicular gear sequence (Bevel Gear type) transfers motion to the center of the hinge joint, where a bearing based mechanism moves the second axis relatively to the first. The Magnetic Encoder, is useful in limiting the movement of the forearm to a specific angle, functioning as a safety measure, (i.e. maximum 120°: natural extensive rotation of the human arm).

Image1: Earlier design (Mk 3) built into a functioning prototype.

3. Electrical Design

A Myoware surface Electromyography Sensor monitors and records the electrical activity of the bicep muscle group. Excitations of the aforementioned muscle are recorded as rises of the output voltage of the sensor, measured by a microcontroller. The measurements are converted to integers (from 0 to 1023) and processed through the appropriate algorithm. Thus, the intended motion (*flexion* or *extension*) and its intensity (unit force) are deduced. The microcontroller, then, sends logical voltage (0V or 5V) as well as PWM (0V to 5V) signals to a Motor Control Board that regulate the provided polarity as well as the voltage supply, respectively. The supply options include a battery pack and a transformer-plug system that connects to the mains electricity.

4. Software Design and Operation

Initially, a calibration process is required. The arithmetic means *MSMmin* and *MSMmax* are produced from measurements on a relaxed and on a strained bicep,

$$ThV = MSM_{min} + k\% * (MSM_{max} - MSM_{min})$$

respectively. The *Threshold Value* (*ThV*) is calculated using the equation:
where *k* is the value corresponding to the balance point between active flexion and active extension. After the system is initiated, it operates as follows: if a Muscle Strain Measurement (MSM) is greater than the ThV, then the motion is interpreted as flexion. The polarity is, thus, set accordingly, and the power provided to the motor is proportional to the MSM value. Whereas, if the MSM value is less than the ThV, the polarity is reversed and the value is considered inversely proportional to the power provided to the motor. Consequently, extension is achieved.

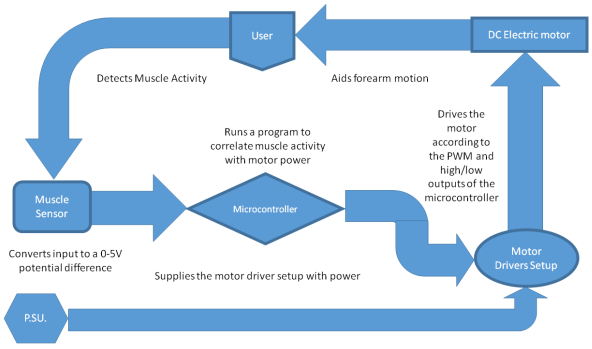

Image 2: Flow chart illustrating system operation

5. Results and Conclusion

Our system has proven to work effectively, with an insignificant input lag. Furthermore, after consulting medical experts, we are certain that our system can be beneficial for patients by either: a) providing constant energetic support for the bicep, or b) providing passive and/or energetic exercise for the bicep, in order to aid recovery. The above are considered to be two areas in which the clinical industry lacks affordable technologies. For that reason we are currently aiming for clinical testing that will lead to the adoption of our apparatus in the treatment of patients.

6. References

Rohrer, W, editor. Επαγγελματικοί Υπολογισμοί Βασικής Μηχανολογίας. 2nd ed., ΙΩΝ, 2005