I-HANDWRIST : Integrated Hand and Wrist Rehabilitation System

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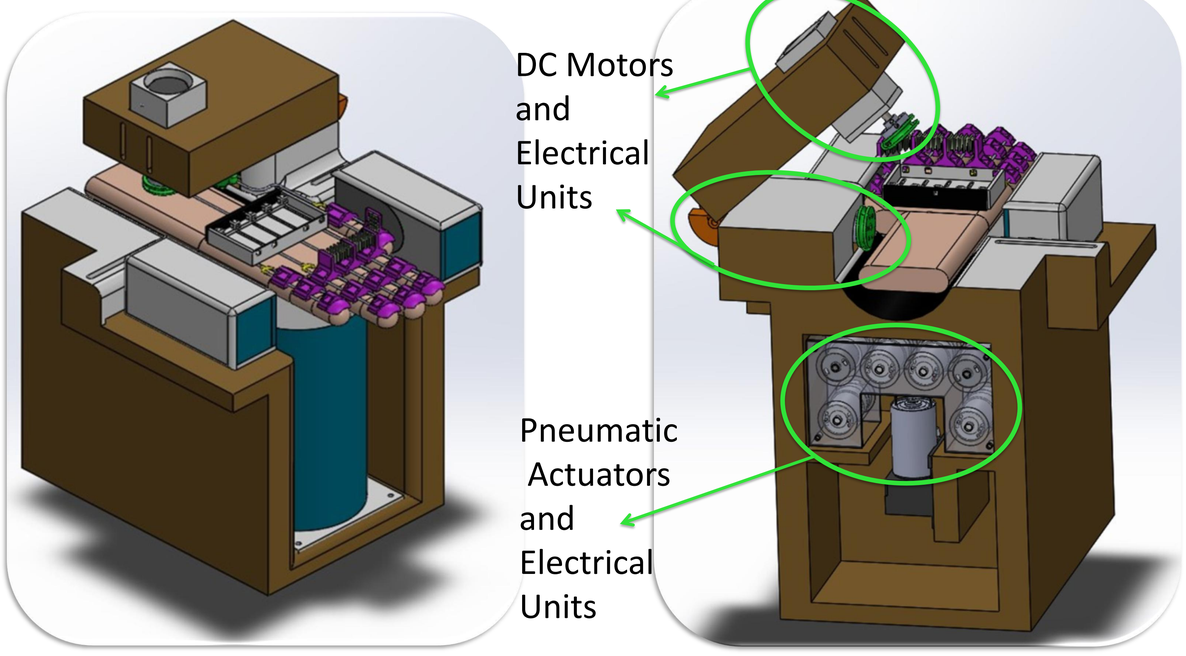
Motivation

- Neuromuscular diseases directly affect the muscle-nerve relationship, progressive muscle weakness is present in most of these diseases, directly affects the upper extremity functions in the human body. The functionalities of the hand and wrist could be lost permanently due to these diseases. As the hand and wrist lose their function, people become unable to perform their daily activities, which makes their lives much harder.[1]
- Successful rehabilitation for patients who have lost the necessary functions in hand and wrist movements can be achieved with intense and continuous therapeutic exercise. Rehabilitation robots provide an effective treatment opportunity compared to traditional treatments for patients who have difficulty in performing repetitive movements without assistance.[2]
- The main objective of this project is to develop and implement a synchronized rehabilitation robots that assist to the human upper-extremity limbs which are the hand and wrist, which aims to restore the motor functions of the hand and wrist.

Originality

- An integrated system that implements tendon driven system and soft robotic technology which will be used together to perform all rehabilitation movements.
- 3 Air pillows will be used, and soft robotic technology will be used to provide Flexion/Extension and Ulnar/Radial deviations movements which realizes the 2 DoFs of the wrist.
- Tendon Cables and 2 Air chambers will be used to provide Extension and Adduction/Abduction movements which realizes the 2 DoFs of each finger including Thumb.
- Hand and wrist exoskeletons to actively assist the traditional rehabilitation process, based on the physiotherapist decision the necessary rehabilitation process can be applied separately to the relevant patients.
- System is suitable for use in the physical therapy and follow-up processes of neurological and neuromuscular patients in hospitals, clinics and physiotherapy and rehabilitation centers. It can be applied in the medical device industry.

I-HANDWRIST Design



I-HANDWRIST Solid Model (Isometric View)

I-HANDWRIST Solid Model (Rear View)

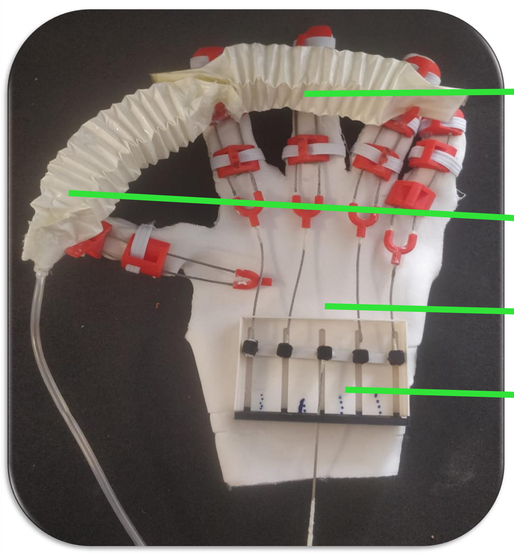
- Two DC Motors (Underactuated) – Seven Pneumatic Actuators
- Tendon Cables – Finger Rings – Slider/Slot mechanism
- Two Air Chambers – Three Air Pillows
- Position sensors (encoder) were used in controlling the Tendon driven system
- Pressure sensors and electrical valves were used in controlling the air pillows

Hand Rehabilitation System Design Features

- Integration of tendon cables and air chambers
- Adaptive to any size of user.
- Under-Actuated design.
- Extension of thumb and 4 digits
- Adduction and abduction of fingers

Wrist Rehabilitation System Design Features

- Soft actuation system.
- Flexion and extension of the wrist.
- Ulnar and radial deviation of the wrist.
- Adaptive to any size of user.
- Main air pillow modularity.
- Lateral air pillows position adjustment.

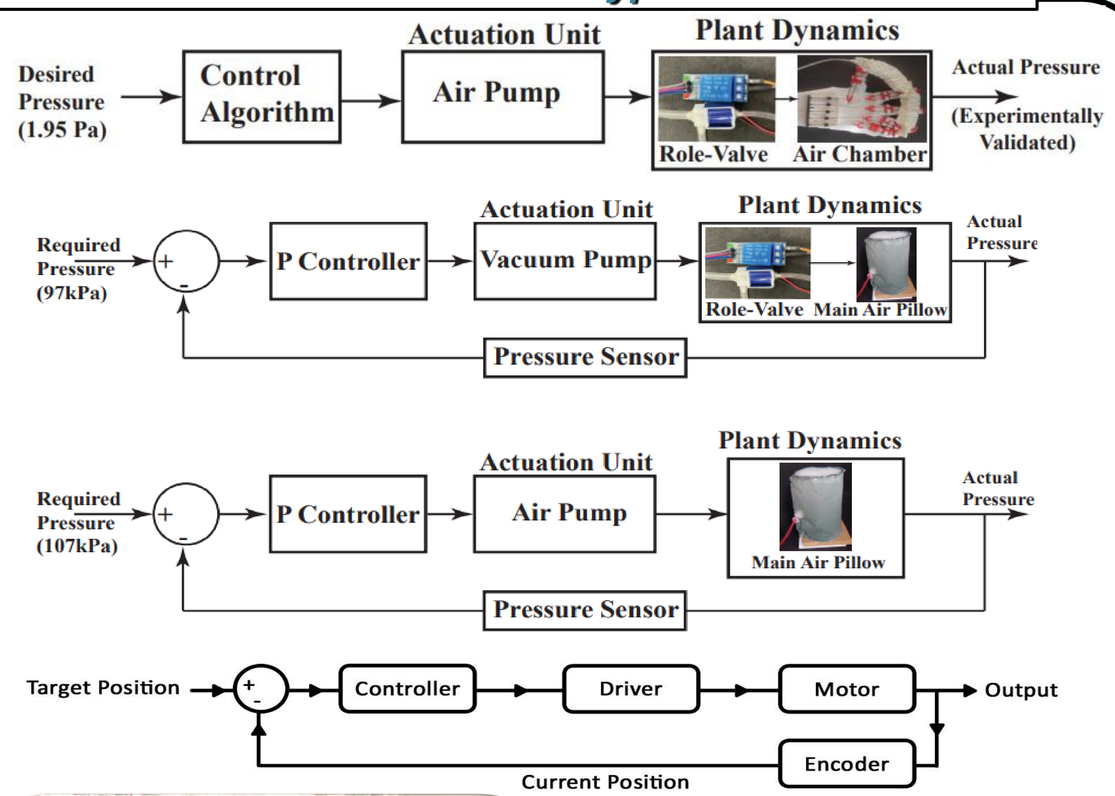


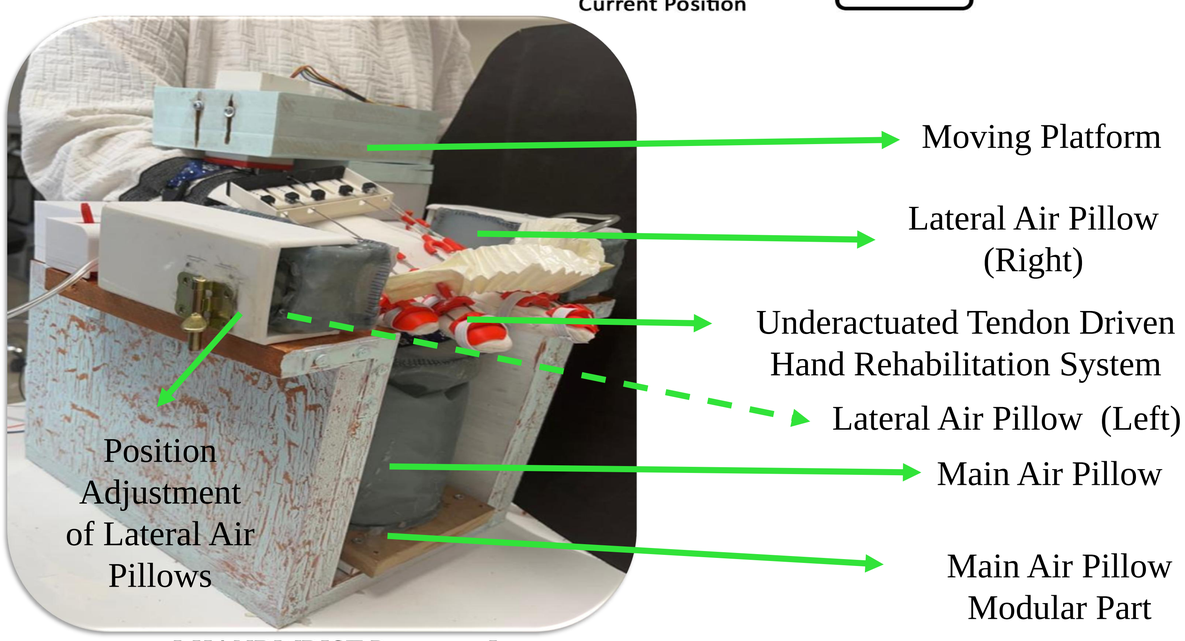
I-HANDWRIST – Prototype I of Hand Rehabiliation Part

Experimentally Evaluated Required torque to fully actuate each finger

Index: 9Nm
Middle: 11.6Nm
Ring: 10.2Nm
Little: 5.9Nm
Thumb: 4.5Nm

Control Architectures and Prototype of I-HANDWRIST





I-HANDWRIST Prototype I

Experimentally Evaluated Required Torques of Ulnar and Radial Deviation of Wrist

Load [kg]	Torque [Nm]	Max Pressure [kPa]	Load [kg]	Torque [Nm]	Max Pressure [kPa]
0,15	0,136	11	0,15	0,136	10
0,25	0,227	11	0,25	0,227	10
0,5	0,454	11	0,5	0,454	10
0,75	0,68	11	0,75	0,68	10

Experimentally Evaluated Required Torques for Flexion and Extension of Wrist

Load [kg]	Main Air Pillow Pressure [kPa]	Torque[Nm]
0.25	5	0.227366
0.5	6	0.454732
0.75	7	0.682098
1	7	0.909464
1.25	8	1.13683
1.5	9	1.364196
2	10	1.818928

Conclusions

- This study presented a novel design for hand and wrist rehabilitation of patients with Neuromuscular diseases. The design supports extension and adduction/abduction movements of the fingers as well as flexion/extension and ulnar/radial deviation movements of the wrist by integrating tendon cables and air pillows.
- While performing the rehabilitation process the feedback is received via different sensors such as position sensors for the tendon system and pressure sensors for the pneumatic system and the feedback is recorded to analyze the rehabilitation program of each patient.
- Mathematical model of I-HANDWRIST is derived from kinematic and dynamic analysis and tested with Simulink environment. Real time control of I-HANDWRIST was done with multiple microcontrollers and two DC motors and seven air pumps/vacuums.
- Future works are planned for I-HANDWRIST to improve system speed and full automation.

Acknowledgement

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References

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