S.P.E.A.R

Soft Pneumatic EMG Assisted Rehabilitation

Aim

SPEAR is an Active Ankle-Foot Orthosis (AFO), aimed at providing a cheap and affordable solution for rehabilitating stroke survivors.

Abstract

- Stroke patients often suffer from Foot Drop, a paralysis of the muscles in the anterior portion of the lower leg, causing an inability or impaired ability to raise the foot from the ankle. This leads to extremities of the foot dragging along the ground while walking, and can cause tripping and other accidents. Presently, patients are trained to walk with canes, and physiotherapy is also prescribed. The physiotherapy requires the presence of a trainer, and these frequent consultations lead to huge expenditure.
- Currently, robotic therapeutic tools exist, but the rigidity does not lend itself to the compliant nature of the body, and are unwieldy. They are bulky and heavy which makes them unwearable under regular usage.
- As a bio-inspired solution, SPEAR aims to provide a soft robotic approach to the physio therapy. The end effectors at the ankle are a set of soft pneumatic actuators, controlled by electromyography signals (EMG). This achieves a reduction of weight at the joint, and can be custom made to fit the patient's needs.

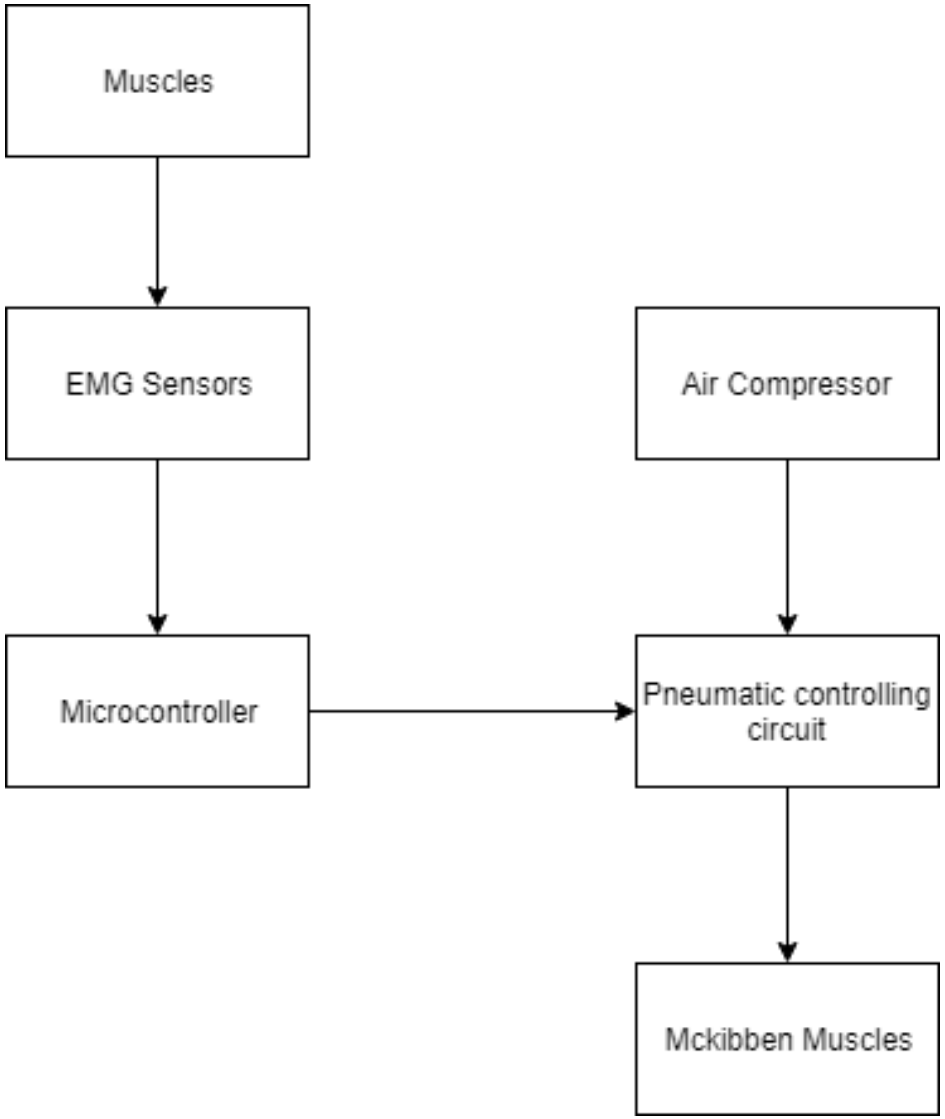
- ***Keywords — Rehabilitative robotics, stroke, foot drop, Soft robotics, soft pneumatic actuators, Electromyography***

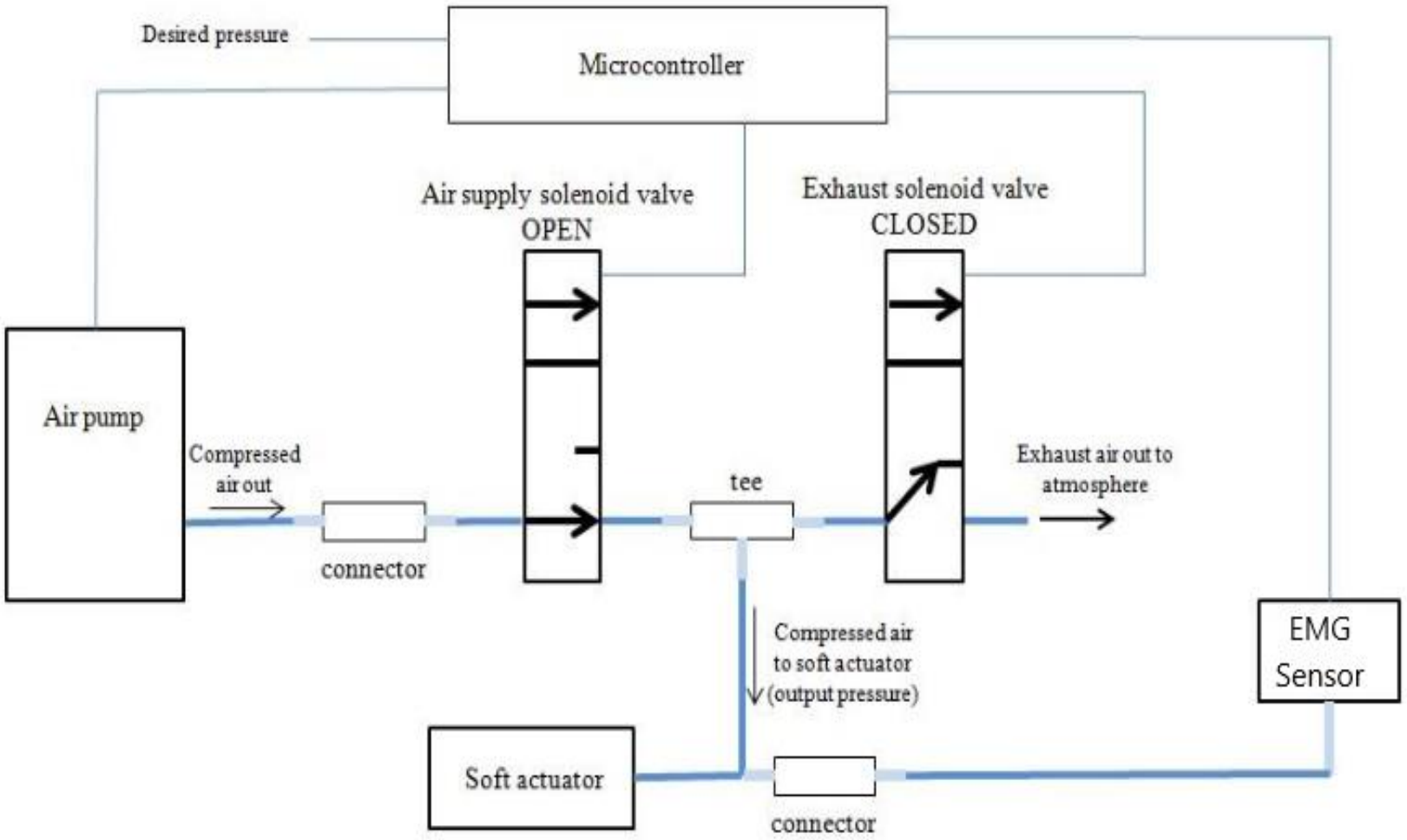
Application

Ease of physiotherapy for those affected with stroke. Physiotherapy is a costly and continuous process, whereas a robotic solution would be a one-time investment. Because of its compliant nature, SPEAR is lighter, smaller and easier to use, contrary to traditional rigid approaches.

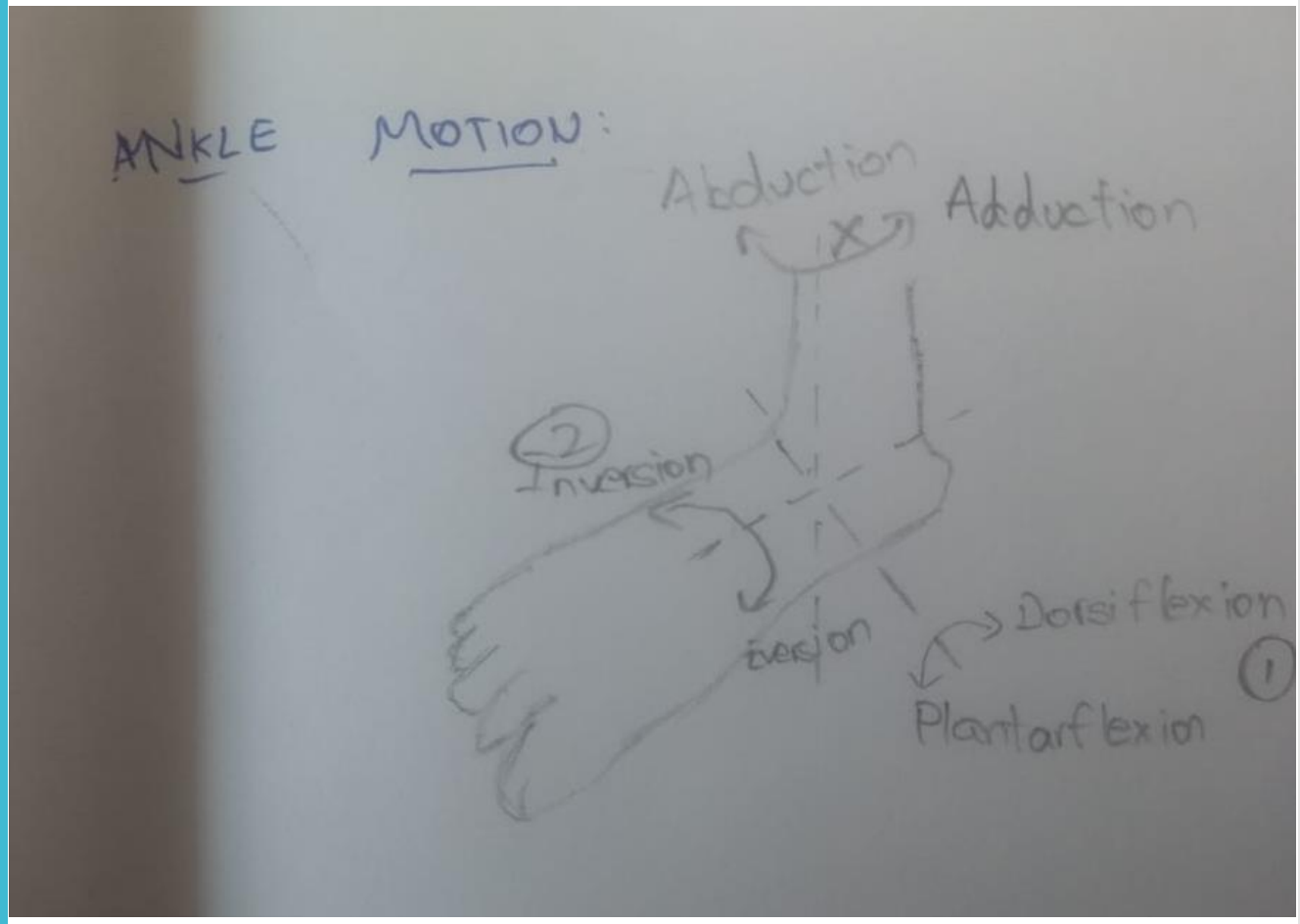
COMPONENTS / PART	Role / Functionality.
Thermoplastic Polyurethane, Nylon Mesh	Fabricate the pneumatic actuator
Air compressor	To compress the air from atmosphere and transfer the compressed air to pneumatic actuators
Solenoid Valve	To control the air flow to pneumatic actuators
MCU	To control the solenoid valve from the data obtained from the corresponding EMG sensors
Electromyographic (EMG) sensor	To measure the electrical activity of muscles

Block Diagram




Desired pressure
Microcontroller
Air supply solenoid valve
OPEN
Exhaust solenoid valve
CLOSED
Air pump
Compressed
air out
connector
tee
Exhaust air out to
atmosphere
Compressed air
to soft actuator
(output pressure)
EMG
Sensor
Soft actuator
connector

Ankle Motion



McKibben Muscles (Soft artificial muscles)

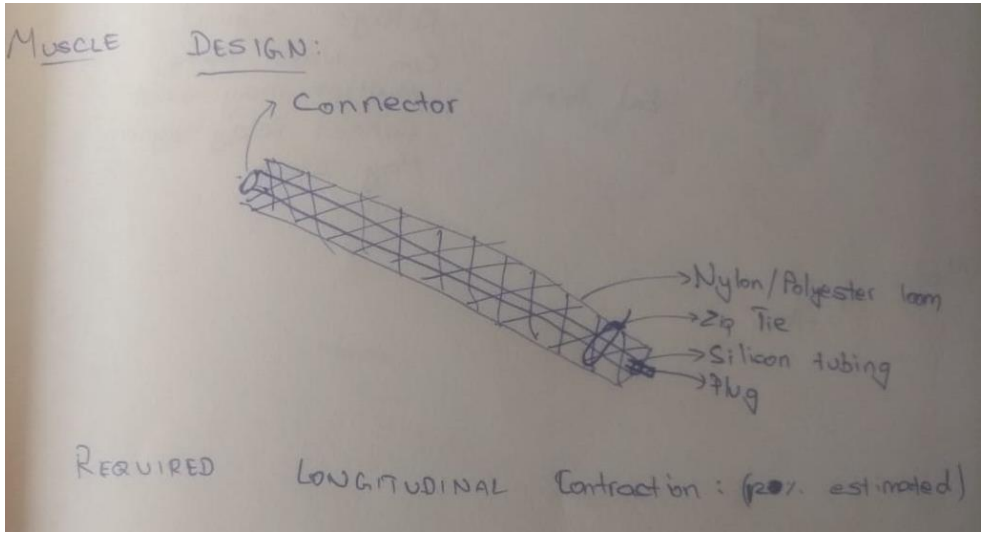
- McKibben Muscles have been fabricated.
- The price of a readymade McKibben muscle is minimum Rs.1500
- Using off-the shelf components, cost has been reduced to an average Rs.150, depending on Muscle size, diameter

Component	Cost(Rs.)
Bladder(Silicon Rubber)	40 - 60
Nylon Mesh Sleeve	40 - 60
Miscellaneous (Connectors, Seals)	50
Total	**150**

Testing Results

Inner Diameter (inch)	Outer Diameter (inch)	Length (cm)	Slack in Nylon Weave	Contraction (cm)	Percentage Contraction
1/3	1/2	20	No	2.5	12.5
1/3	1/2	20	Yes	0.5	2.5
1/2	5/8	30	No	3	10

Muscle Test (Video)

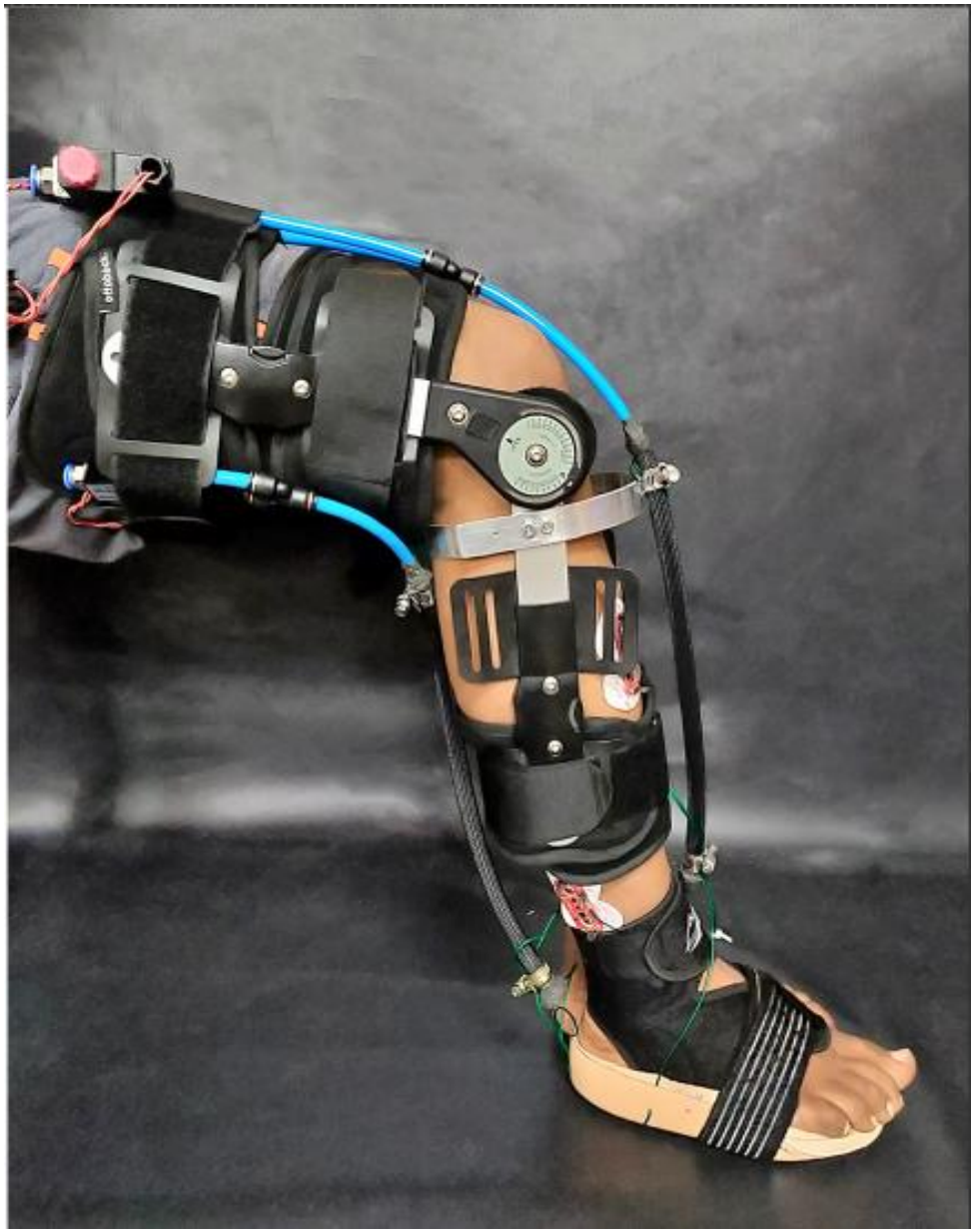


Prototype (120˚ range of motion)

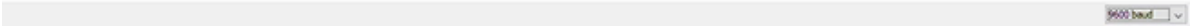
Dorsiflexion

Plantarflexion

Orthosis Design



EMG Dynamic Thresholding (Video)

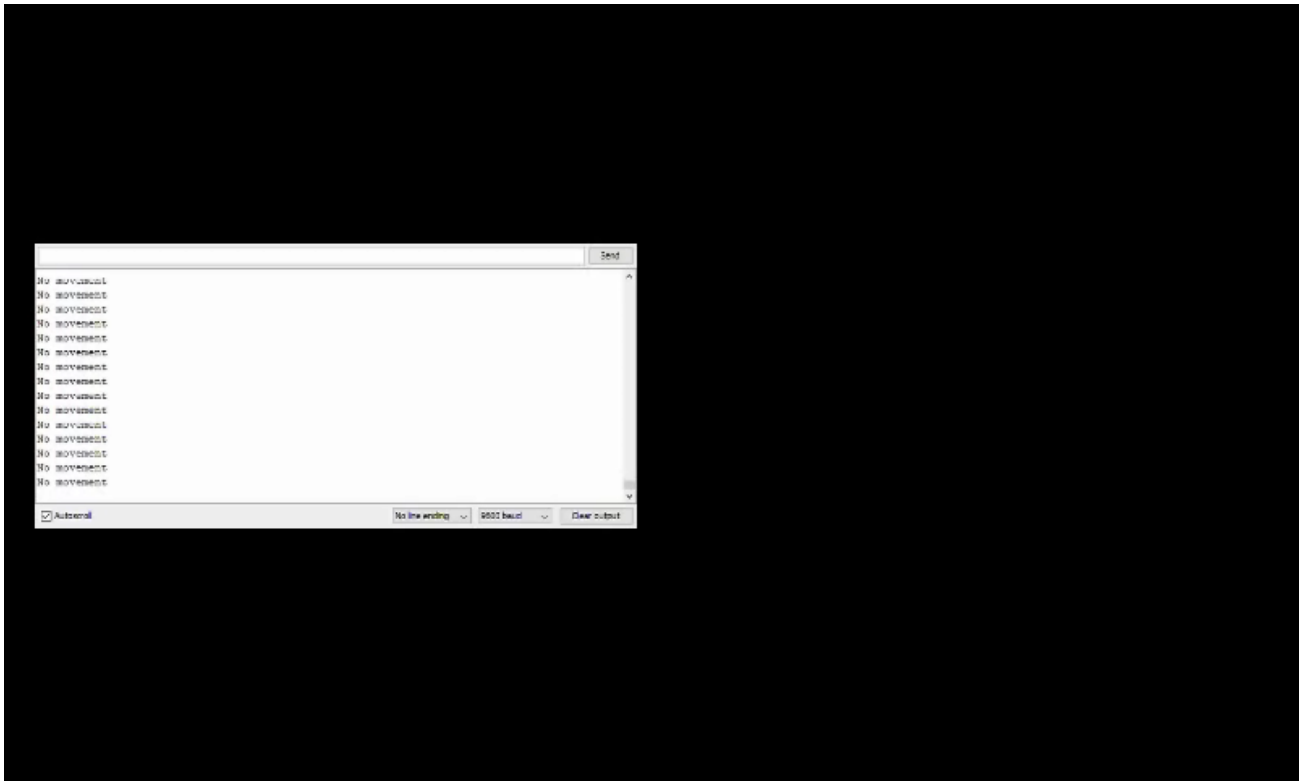


Tibialis Anterior
for Dorsiflexion

EMG Voltage-Time Graph

- Figure shows the voltage time graph obtained after the application of the Kalman Filter to both signals, and the threshold lines calculated using the above formula.

EMG Intent Estimation (Video)



Working Video

Surface
EMG
Calibrating

Future Work

The Orthosis can be extended to Inversion and Eversion motion in the ankle.

The Orthosis which has primarily been optimised for rehabilitation can be upgraded to Exoskeleton for the lower limb.

Expandability is present for machine learning algorithms for greater accuracy of EMG intent estimation.

The main features of this exoskeleton:

1. Soft McKibben muscles provide actuation, eliminating rigidity and preventing damage to the user

2. Autonomous control of the Lower limb with Electromyography signals.