SAPIENZA UNIVERSITÀ DI ROMA

WAKE-up

iit ISTITUTO ITALIANO DI TECNOLOGIA

PROJECT SEED

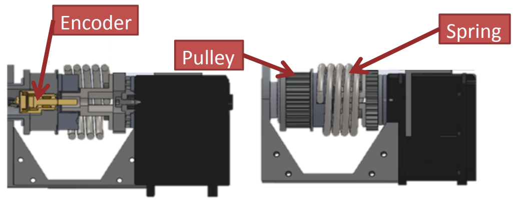
WAKE-up: a Wearable Ankle Knee Exoskeleton

The **WAKE-up** Is a Wearable Ankle–Knee Exoskeleton developed to assist the walk in children affected by Cerebral Palsy (CP).

It is made up by two modules, one for the Knee and one for the Ankle, form the device. This modules can work together or one by one, depending from the gait problem.

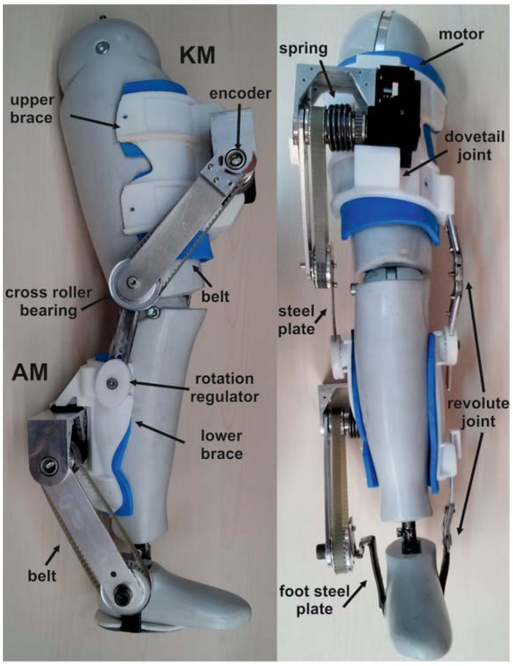
The difference between the passive orthosis actually used for these kind of disorders is that with the WAKE-up the subject does not receive the therapy in a passive way but the device can interact actively with him/her, changing the stiffness value in function of his/her motor improvements. Specifically, the device can apply a corrective/perturbative action on the joint motion assisting or less the subject only when requested.

The prevalence of CP ranges is from 1.5 to 2.5 per 1000 live births and it is influenced by the weight and the gestational age. The CP comports gait disorders and one of the most important is the *Toe Walking*. In this particular case the children walk putting his weight on the toes..



Target specification of the Wake-up

- Bi-articular assisted orthosis, ach module can be utilized alone
- Suitable for patients aged 5-8 years (max mass 2.5 kg)
- To ensure an high level of safety of subjects
- To assist the drop foot gait working as a Knee Ankle Foot Orthosis with an adjustable stiffness via software



Mechanical Design

The actuation system is based on a Series Elastic Actuator SEA. Power transmission is achieved by timing belt and pulleys (1.5 reduction) and it is mediated by a torsion spring of 3.0 Nm/rad. Motors are high-torque digital servos with an embedded positional controller. Torsion spring deflection is measured by an absolute encoder embedded in the transmission shaft. Frame is composed by two braces attached to thigh and shank and its length is adjustable. Quick release system, which is composed by sliding dovetail joints, is designed between motors and brace. Two revolute joints connect the two braces together and the lower brace with a foot steel plate that is inserted into the shoe. Phases of gait are estimated by foot switches placed under the sole.

Orthosis 3D Prototyping

The orthosis where to fix the mechanical components are made by the 3D prototyping technique. The first step of the design work was to acquire and digitalize with a 3D scanner (FARO ScanArm V3,UK), the surface of a lower limb. Then, the digital surface of the limb was imported in the 3D design software where the surface was processed to extruded a shells with thickness of 4 mm from the surface acquired. This method is used to obtain a greater homogeneous contact between the skin surface and the internal surface of the orthosis. In order to make easier the wearability for children, an ad-hoc connection system between the braces and the motors was designed. It is composed of two sliding dovetail joints, one for each module, where the motors can be easily inserted after that subject has worn the braces. This sliding, the joints for the torque transmission and the orthosis links form an all-in-one with the shell. The second step was the effective production of the orthosis and joint links thanks to a 3D printer (S250, China & Dimension, USA), that works with ABS (Acrylonitrile butadiene styrene).

Sensor Logic

To identificate the gait cycle, a sole was sensorized with four foot switches and the ankle and knee modules with one IMU for each. In the SEA the degree of rotation between the spring and the motor is controlled by a Absolute Magnetic Shaft Encoder. The sensors are managed by a MyRio board (NI, USA). This set-up permits the 2D kinematic reconstruction and analysis of the gait and the torque estimation for the knee and ankle joint.

Parameters	RMSE
Joint angle (°)	1.3
Spring offset (°)	0.8
Spring stiffness (Nm/rad)	0.7
Spring amplitude (°)	0.9
Torque offset (Nm)	0.34
Torque amplitude (Nm)	0.14