Design of an active stance-control knee-ankle-foot orthosis to assist the gait of incomplete spinal cord-injured subjects

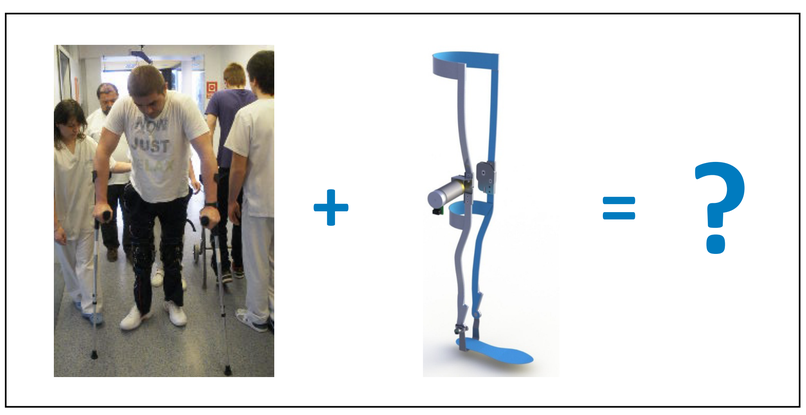
J.M. Font-Llagunes[1], R. Pàmies-Vilà[1], F. Romero[2], J. Alonso[2], U. Lugrís[3], J. Cuadrado[3]

1. Dept. Mechanical Engineering and Biomedical Engineering Research Centre (CREB), Universitat Politècnica de Catalunya (UPC), Spain
2. Dept. of Mechanical Engineering, Energetics and Materials, Universidad de Extremadura (UEX), Spain
3. Laboratory of Mechanical Engineering, Universidad de La Coruña (UDC), Spain

E-mail: **josep.m.font@upc.edu**

Introduction

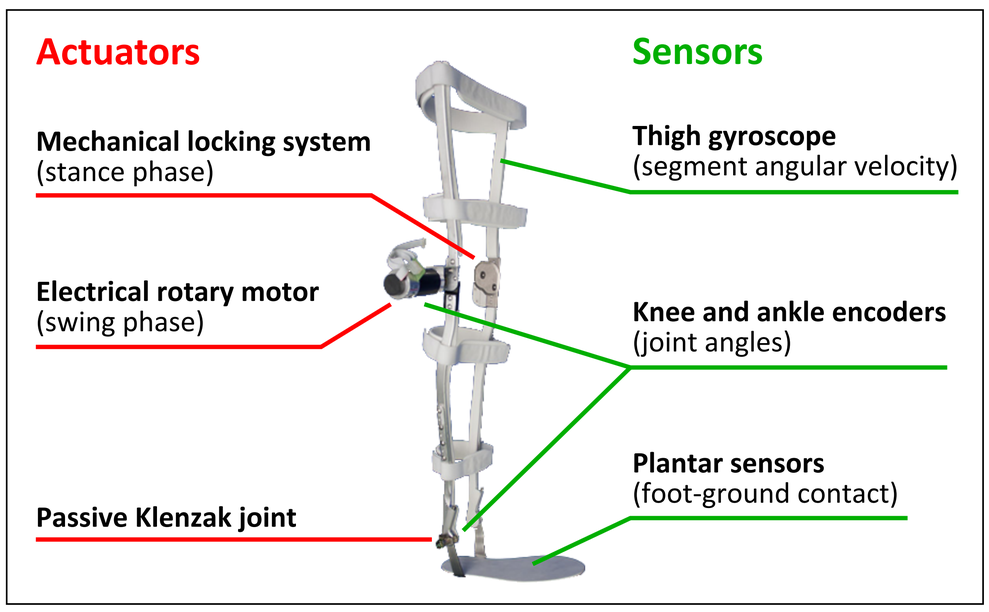
- National project: **Application of multibody dynamics techniques to active orthosis design for gait assistance** (UDC, UEX, UPC).
- **Project goals**:
  - Simulation of the gait of spinal cord injured (SCI) subjects equipped with active orthoses.
  - Design of an active orthosis for incomplete SCI subjects.



- **The project involves different tasks**:
  - Preparation of the experimental equipment.
  - Development of computational models for healthy and incomplete SCI subjects.
  - Design and control of an active orthosis prototype.
  - Inverse/forward dynamic analysis of assisted gait.

Active orthosis prototype

- **Stance-Control Knee-Ankle-Foot Orthosis (SCKAFO)** aimed at assisting SCI subjects with levels C or D in the ASIA scale.
- Subjects are able to control hip flexors, but have **partially denervated muscles actuating the knee and ankle joints**.



- Different **orthosis prototypes** for the right and left legs:

CAD model

Left prototype

Subject with orthoses

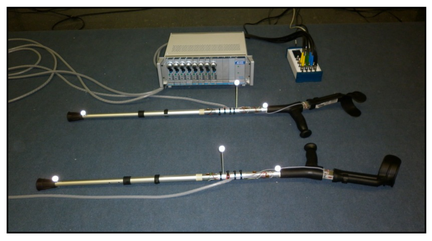
Experimental equipment

- **Biomechanics Laboratory**:
  - 12 OptiTrack FLEX:V100R2 cameras.

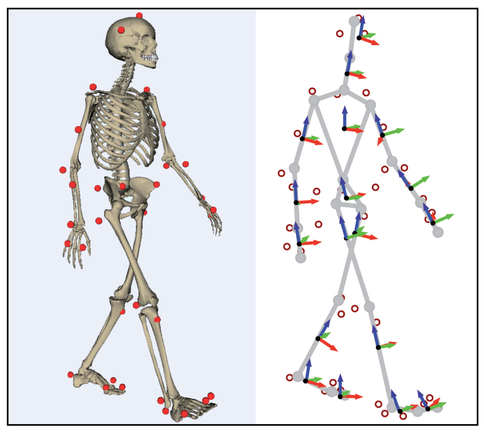
Passive reflective markers

  - 2 AMTI AccuGait force plates.

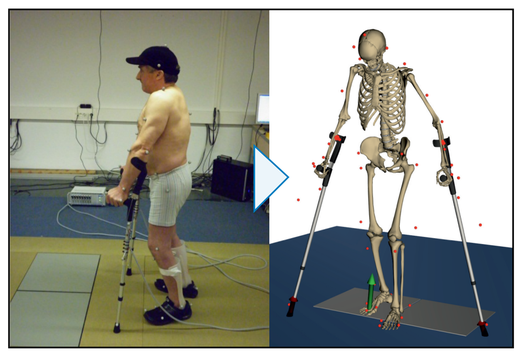
- **Instrumented crutches**:
  - Motion capture: 3 markers/crutch.
  - Force measurement: extensometry.
  - Calibration using force plates.
  - Synchronized with motion capture system and force plates.



Computational model



- **Healthy subject model**:
  - 37 markers.
  - 18 bodies, 17 spherical joints.
  - 57 degrees of freedom.
  - 228 coordinates (natural + angular).
  - Two segments for each foot.
  - No HAT simplification.
  - BSP: anthropometric data and correlation equations.
- **SCI subject model**:
  - Crutches rigidly connected to hands.
  - 252 total coordinates.
  - Up to 4 simultaneous contacts: Indeterminacy problem.
  - Standard values of BSP are not applicable: use of densitometry.



Conclusions and future work

- We have developed a **computational-experimental tool** that allows to obtain kinematic and dynamic information of the gait of **SCI subjects using crutches and active orthoses**.
- **Two innovative knee-ankle-foot active orthoses** have been built and tested on healthy subjects.
- The **inverse dynamic analysis of orthosis-assisted gait** can be performed using the presented tools.
- **Future work**:
  - Try the presented prototypes on SCI subjects in a hospital environment.
  - Use the computational tool to test different control strategies.
  - Investigate the subject-orthosis force sharing problem.
  - Understand the subject's motor adaptation to robotic assistance.