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

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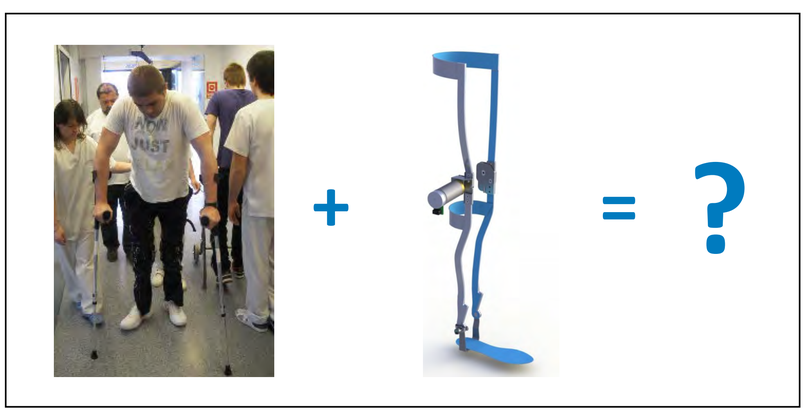
Introduction

- 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.



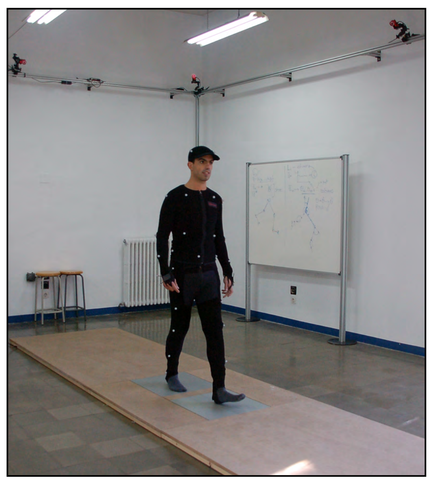
- **The project involves different tasks**:
  - Preparation of the experimental equipment.
  - Development of computational models for healthy and incomplete SCI subjects.
  - Design and control of an active orthosis prototype.
  - Inverse/forward dynamic analysis of assisted gait.

Experimental equipment

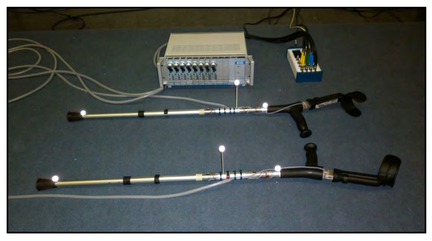
- **Biomechanics Laboratory**:
  - 12 OptiTrack FLEX:V100R2 cameras.

Passive reflective markers

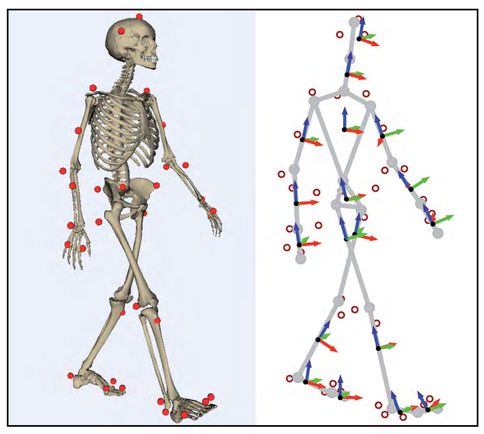
  - 2 AMTI AccuGait force plates.



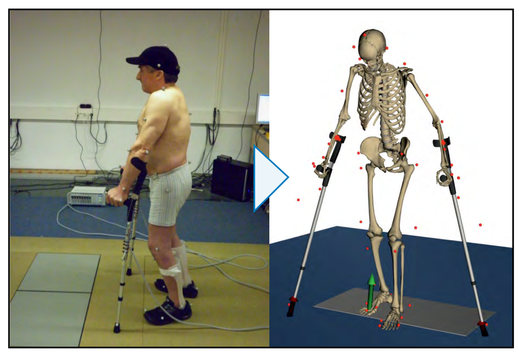
- **Instrumented crutches**:
  - Motion capture: 3 markers/crutch.
  - Force measurement: extensometry.
  - Calibration using force plates.
  - Synchronized with motion capture system and force plates.



Computational model

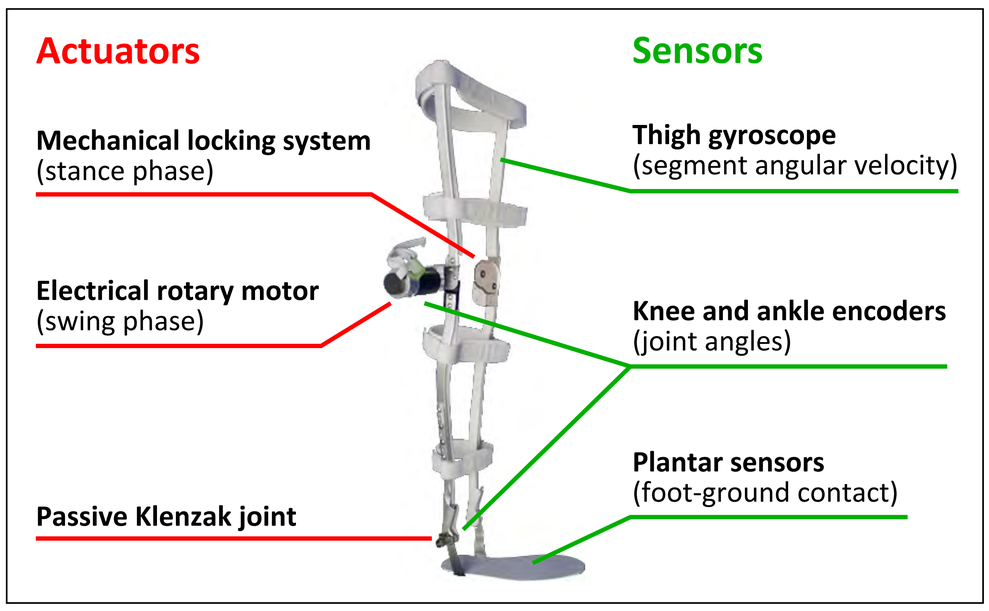


- **Healthy subject model**:
  - 37 markers.
  - 18 bodies, 17 spherical joints.
  - 57 degrees of freedom.
  - 228 coordinates (natural + angular).
  - Two segments for each foot.
  - No HAT simplification.
  - BSP: anthropometric data and correlation equations.
- **SCI subject model**:
  - Crutches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



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

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.