ScuDo
Scuola di Dottorato – Doctoral School
WHAT YOU ARE, TAKES YOU FAR
XXXII Cycle

Human-machine interaction

Carlo De Benedictis
Supervisor: Prof. Carlo Ferraresi

Three activities in the field of human-machine interaction are presented:

Robotized system for the clinical assessment of postural stability

- **Research context**
- Postural control, managed by the central nervous system, is evaluated observing the response to a perturbation.
- The typical mechanical perturbations are the base platform alteration and pulling forces exerted by cables.
- A robotized system, able to apply a controlled impulsive perturbation and to analyze the human response, may be more flexible and scalable in terms of direction and energy of the stimulation impressed.

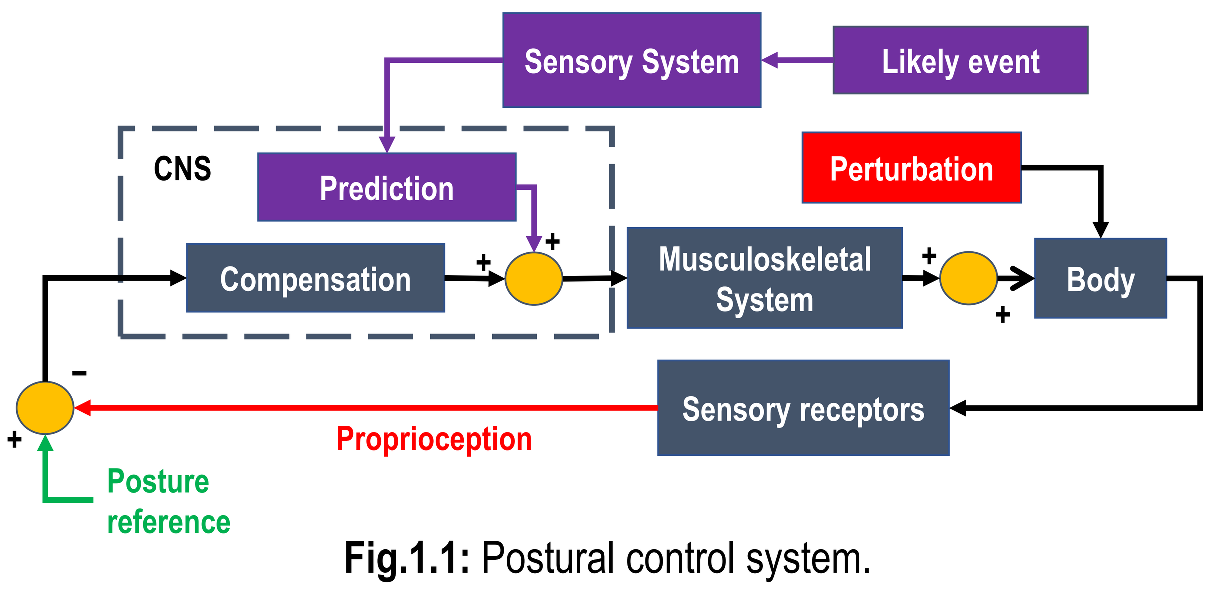

Fig.1.1: Postural control system.

- **A preliminary study**
- A manual perturbator, equipped with a load cell and an accelerometer, has been used to impress perturbations on healthy subjects, standing on a force platform and instrumented with a second accelerometer and EMG.
- A consistent correlation between the impulse (time integral) of the contact force and the body response has been evidenced.
- **A second step: modelling a mechatronic system**
- A mechatronic system able to control the impulse of the stimulation has been studied, consisting of a pneumatic cylinder, two flow proportional valves and an instrumented striker, impacting with the body mass.

Fig.1.2: Experimental setup of the preliminary study.

- A non linear control has been chosen due to friction and valve non linearities, based on sliding mode technique.
- The effectiveness of the control logic has been proved, even if subject to the accurate identification of some physical parameters.
- A clinical evaluation of postural control stability could be performed by correlating the body momentum variation with the contact force impulse.

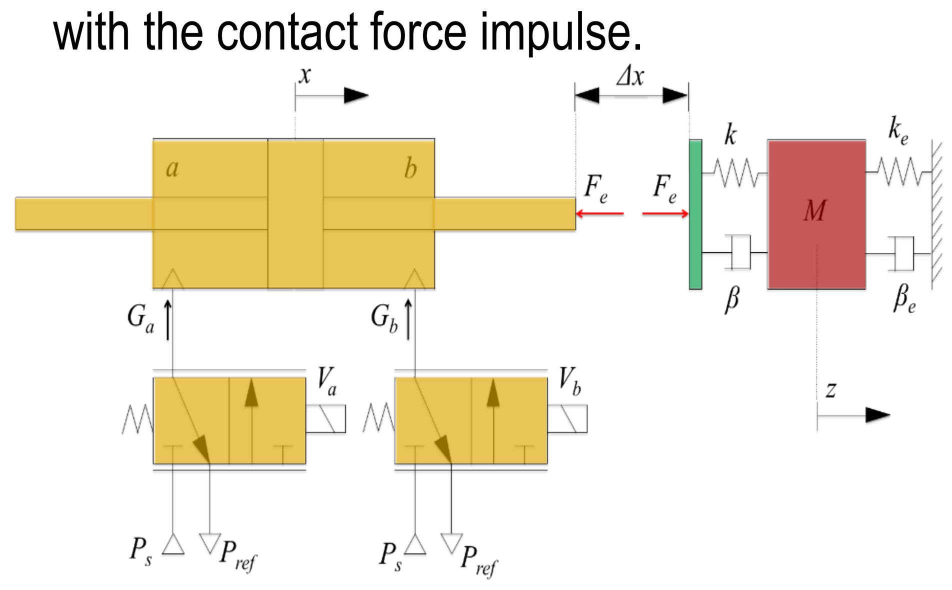

Fig.1.3: The model of the mechatronic system.

- **Future work**
- Development of an experimental setup of the device;
- Implementation and test of the control logic;
- Realization of new clinical trials;
- Improved identification of the parameters related to the stimulation and the body response.

Design of Ankle-Foot Orthoses (AFO) based on natural joint kinematics

- **Context and issues addressed**
- The arbitrary location of the mechanical hinge in Hinged Ankle-Foot Orthoses (HAFO) leads to unnatural patterns of motion at the other foot joints.
- The variability of the ankle rotation axis requires an appropriate design of the hinge.
- High device-limb compatibility is required to improve the effectiveness of the treatment.

Fig.2.1: HAFO prototype and marker positioning.

- **Novel contributions**
- The proposal of a new methodology for the in-vivo evaluation of ankle joint kinematics, based on the calculation of the Instantaneous Helical Axis (IHA) over stereo-photogrammetric data.

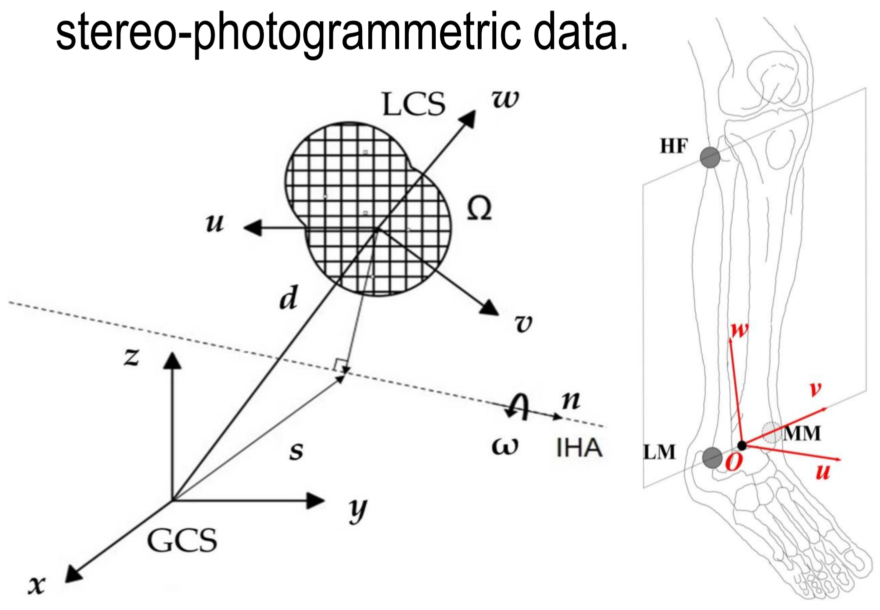

Fig.2.2: Left: representation of the IHA and its parameters. Right: lower limb reference system.

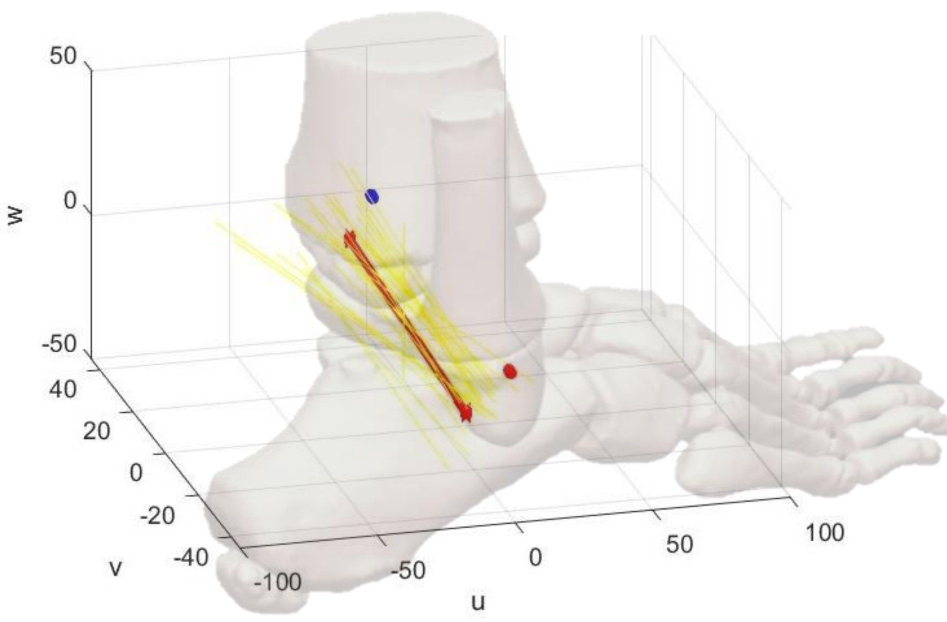

Fig.2.3: Axode of IHAs (in yellow) in a walking trial: the malleoli are shown in red and blue dots.

- The realization and testing of a special prototypal HAFO with floating axis of rotation.
- The realization of dynamic orthoses based on 3D scanning of the subject's limb, built in additive manufacturing, and tested in terms of durability, shape and comfort.

Fig.2.4: Prototypes of dynamic AFO built in additive manufacturing.

- **Future work**
- Improvement of the methodology for the in-vivo kinematic analysis of the ankle joint, concerning the experimental and numerical procedures;
- Mechanical characterization of the devices, by means of stiffness measurements in laboratory and FEA.

Design issues of a Haptic Device with Wire-Driven Parallel Structure

- **Description of the activity**
- This activity has been based on the study of a redundant parallel cable-driven robot, provided with haptic feedback, used as a master unit for telemanipulation.
- The requirements of a device with such structure have been outlined, in terms of:
  - i. the definition of the fixed frame and arrangement of the wires;
  - ii. the kinematic description and workspace evaluation;
  - iii. the choice of the actuators;
  - iv. the control logic.

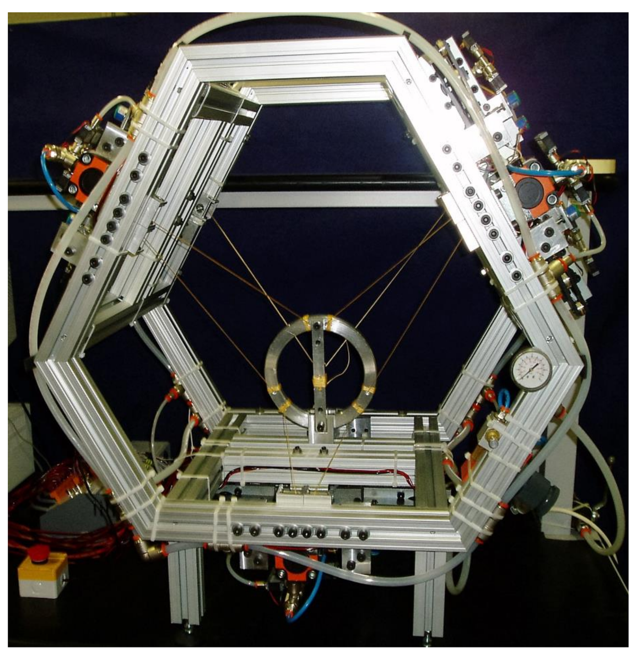

Fig.3.1: The prototype of the master unit.

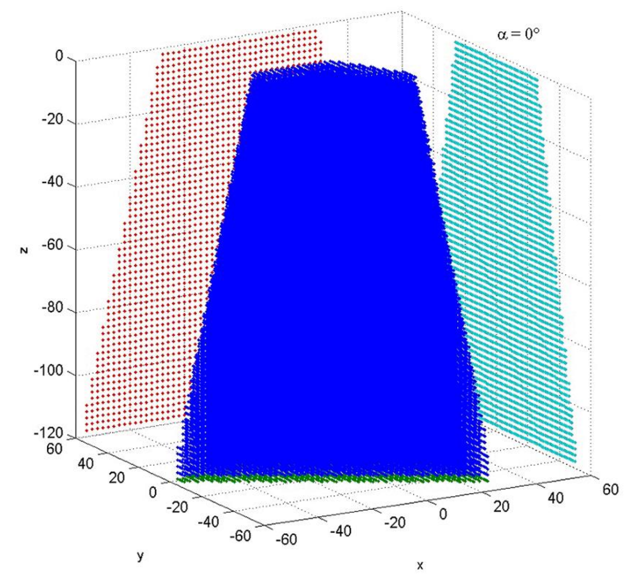

Fig.3.2: The positional workspace of the device, projected on the coordinate planes.

- The study has evidenced that several improvements are possible, as:
  - i. the definition of special indices to evaluate the workspace characteristics of devices with different structures;
  - ii. to take into account the non-ideal characteristics of the system, especially concerning the wire paths and deformability, or friction, in the design process;
  - iii. to overcome the limited strokes of pneumatic actuators.

Published works

- De Benedictis, Carlo; Franco, Walter; Maffiodo, Daniela; Ferraresi, Carlo (2017) Control of force impulse in human-machine impact, In: Advances in Service and Industrial Robotics - Proceedings of the 26th International Conference on Robotics in Alpe-Adria-Danube Region, RAAD 2017 / Ferraresi C., Quaglia G. Springer International Publishing, pp 9, pagine 956-964, ISBN: 978-3-319-61276-8
- Ferraresi, Carlo; De Benedictis, Carlo; Pescarmona, Francesco (2017) Development of a Haptic Device with Wire-Driven Parallel Structure, In: International Journal of Automation Technology Fuji Technology Press, pp 11, pagine 385-395, ISSN: 1881-7629
- Ferraresi, Carlo; De Benedictis, Carlo; Franco, Walter; Maffiodo, Daniela; Leardini, Alberto (2017) In-vivo analysis of ankle joint movement for patient-specific kinematic characterization, In: Proceedings of the Institution of Mechanical Engineerings. Part H, Journal of Engineering in Medicine SAGE Publications Ltd, pp 8, pagine 831-838, ISSN: 0954-4119
- Leardini, A.; Ferraresi, C.; De Benedictis, C.; Franco, W.; Maffiodo, D. (2016) Design of Hinged Ankle-Foot Orthosis based on natural joint kinematics, In: Foot and Ankle Surgery, pp 1, pagine 34-34, ISSN: 1268-7731

List of attended classes

02LWHRO	–	Communication	(16/02/2017, 5 hours)
01QORRO	–	Writing Scientific Papers in English	(23/03/2017, 15 hours)
03LCLRO	–	Epistemologia della macchina	(05/04/2017, 20 hours)
02IYJRO	–	Servosistemi meccanici	(08/06/2017, 20 hours)

Didactic assignments

- 02IKKMV Meccanica applicata ai sistemi biomedici (AA-ZZ) – Tutoraggio di laboratorio
- 07BOTMN Meccanica applicata alle macchine (AA-CZ) – Esercitazioni in aula e in laboratorio