Dispositivi indossabili basati su tessili elettronici per lo sviluppo di sistemi aptici

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Alloderma project (1)

International pre-competitive scientific research

Development of new hi-tech products

Alloderma project (2)

- Coordinator: Mectex Spa
- Scientific director: Silvio Faragò, Stazione Sperimentale per la Seta (SSS)
- Partners
  - Mectex Spa
  - Stazione Sperimentale per la Seta (SSS)
  - Centro Interdipartimentale Piaggio (Università di Pisa)
  - Istituto di Tecnologie Industriali ed Automazione ITIA (CNR)
  - ELSE Srl
  - Stamperia di Lipomo
  - Castagna Spa
- Funded by Regione Lombardia.

RegioneLombardia

Research aims

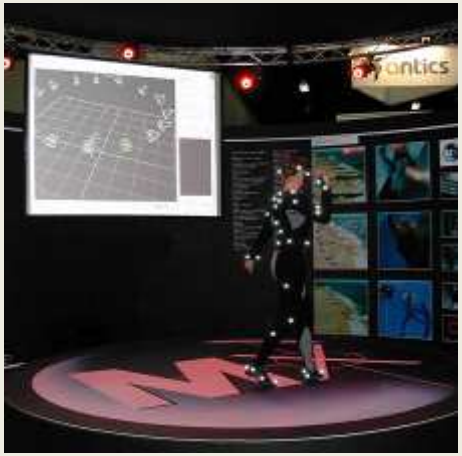
- Sensing garments
  - Human motion/posture detection
  - Conductive Elastomer (CE) sensors
    - Piezoresistive effect
- Provide new tools to be applied in the field human movement monitoring
  - Portable
  - Comfortable for the user

Human movement monitoring

- Movement monitoring
  - Gesture classification
  - Human activity classification
  - Motion capture/analysis
- Applications
  - Rehabilitation
  - Sport
  - Human Machine Interaction

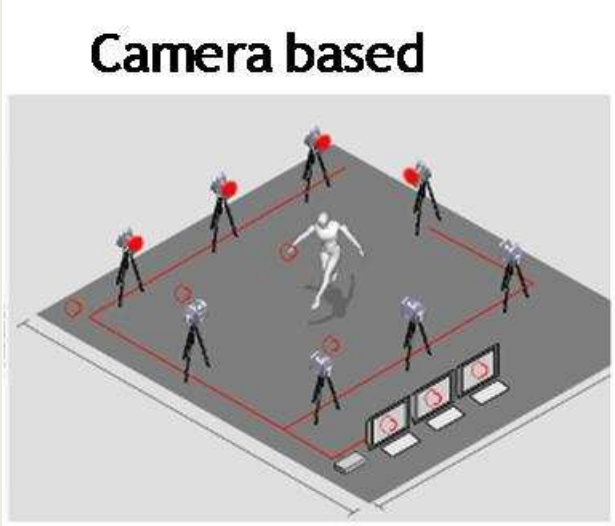
Movement analysis instrumentation (1)

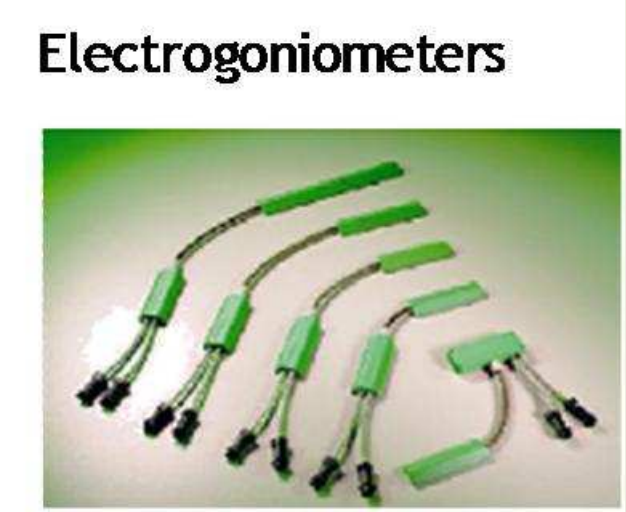
- Standard “off the shelf” motion capture systems
  - Electromechanical
    - Rigid part on human body
    - Soft tissue
    - Tricky positioning
    - Multi DOF joints (shoulder)
  - Optical
    - Restricted environment
    - Expensive
  - Magnetic
    - Interference by ferroelectric materials and electromagnetic fields
  - Inertial
    - Rigid part applied on each articulation



Movement analysis instrumentation (2)

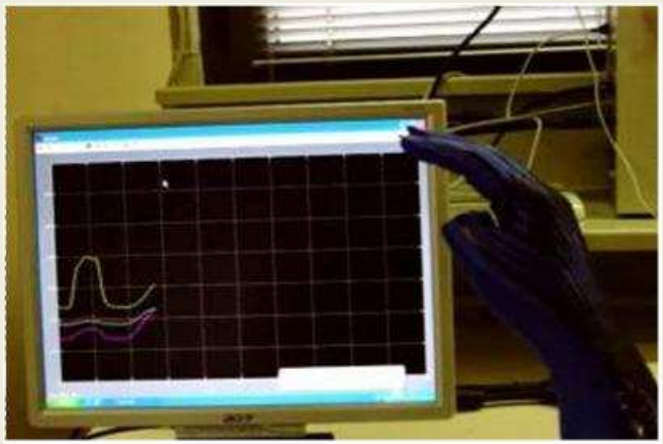
- Standards
  - Accurate
  - Un-portable
  - Limited to structured environments
  - Obtrusive parts on the user





Sensing garment based on conductive elastomer sensors

- Main Idea
  - Distribution of a set of sensors on an elastic and adherent garment
  - During the user movement, the system generates a set of signals which are related to local fabric deformations
- Data Interpretation
  - Generated signals related to user movements



Materials & Methods (1)

- Sensors: CE materials
  - Mixture of conductive particles and silicon rubber
  - Piezoresistive effects
    - A fabric deformation can be related to a sensor electrical resistance variation
  - Integrated on a Lycra-cotton fabric
    - No modification of the fabric mechanical properties
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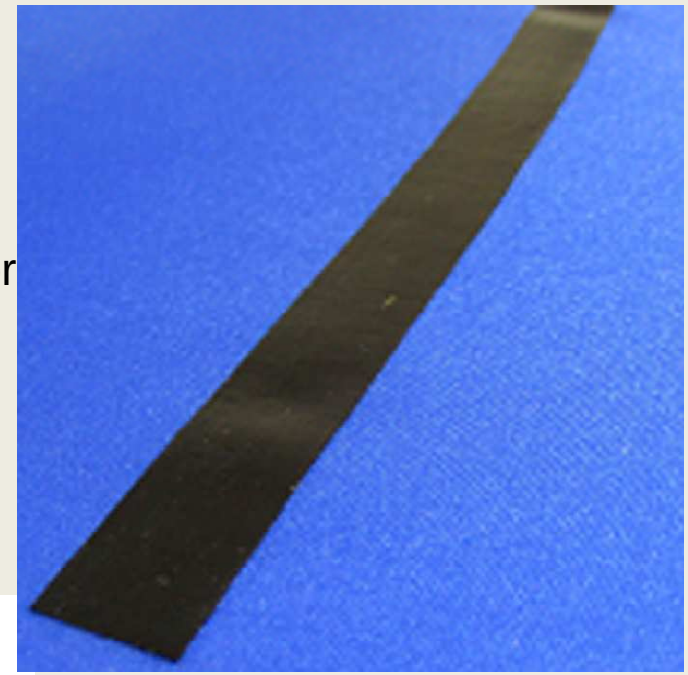
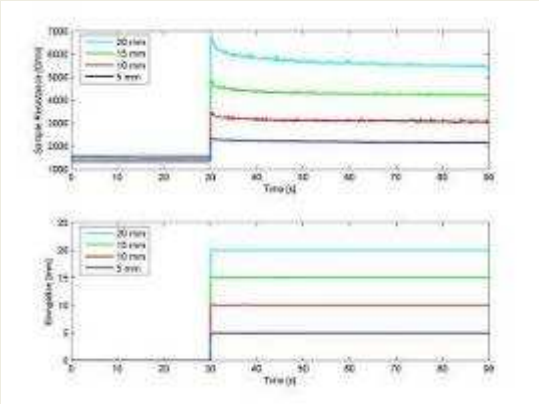
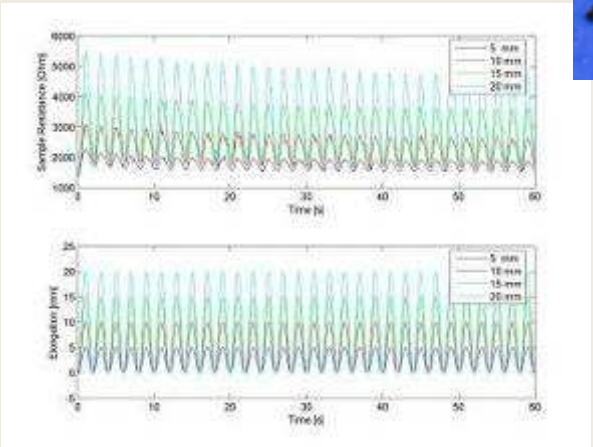
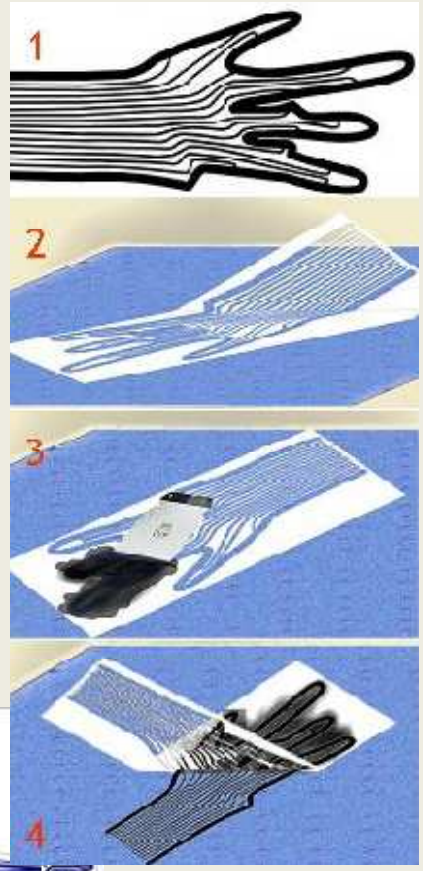


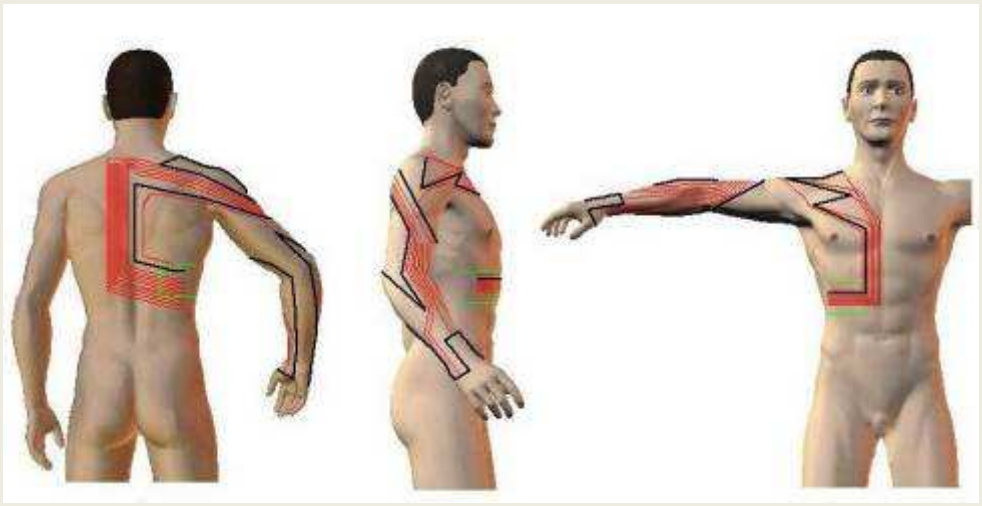


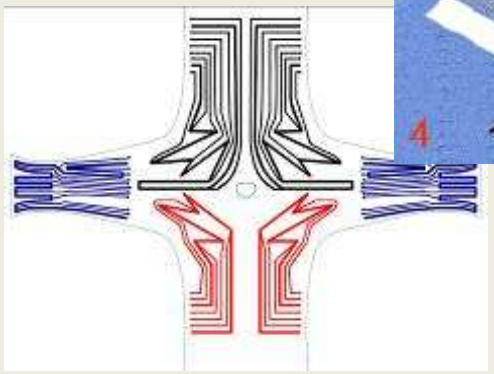


Materials & Methods (2)

- Production process
  - Mask design
    - Determination of sensors position and orientation
      - Redundant sensor set around joints to be monitored
      - Validate the design: experimental trials
    - Topology traced on a three-dimensional model of the human body
  - Mixture preparation, deposition and vulcanization





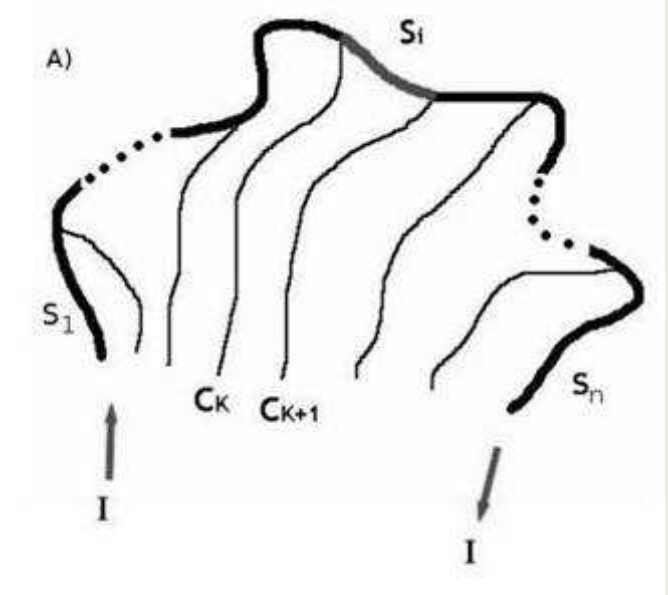


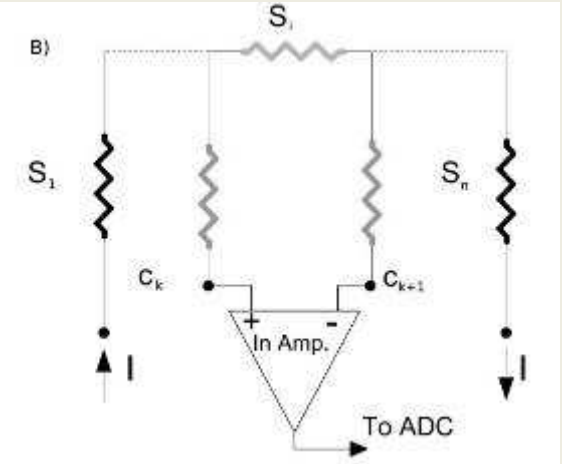
Materials & Methods (3)

- Sensing Garments Main features
  - Elasticity, lightness, good comfort for the user
- Drawbacks
  - Textile substrate (hysteresis, relaxation times)
  - Different sensor positioning after re-wearing
    - The “initial” status changes

Electrical Topology & acquisition front-end

- Topology and electrical model
  - Sensor line
    - S_1-S_n
  - Connections
    - Piezoresistive, c_i
  - No metallic wires
    - Comfort
    - Mechanical resistance
- Electronic interface
  - Piezoresistive connection compensation





The CE Sensing Glove (1)

- Sensing glove
  - 20 piezoresisitive sensors
  - Distributed over the hand joints

References:
- Tognetti, Lorussi, De Rossi, “Wearable Kinaesthetic System for Capturing and Classifying Upper Limb Gesture in Post-Stroke Rehabilitation”, Journal of NeuroEngineering and Rehabilitation, Vol. 2, N. 8, March 2005.
-Lorussi, Scilingo, Tesconi, Tognetti, De Rossi, “Strain sensing fabric for hand posture and gesture monitoring”, IEEE Transactions On Information Technology In Biomedicine, Vol 9, N. 3, pp. 372-381, September 2005
-Tognetti, Carbonaro, Zupone, De Rossi, “Characterization of a Novel Data Glove Based on Textile Integrated Sensors”, 28th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, New York, USA, September 2006.

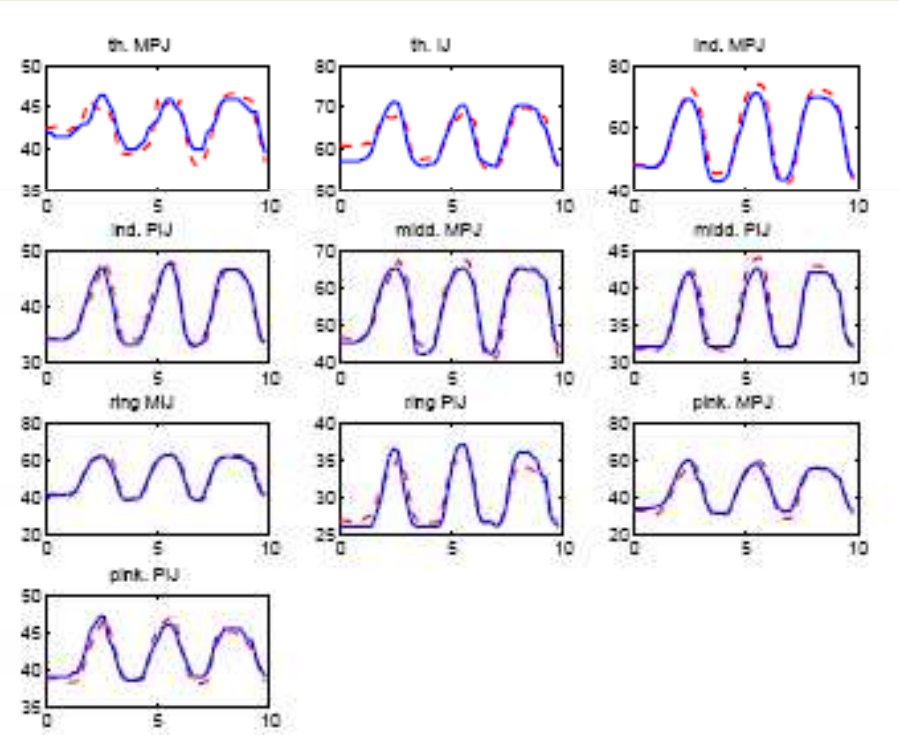
The CE Sensing Glove (2)

- Hand gesture classification
  - ASL recognition + basic hand grips

The CE Sensing Glove (3)

Results

– Angle measurement: 5% error as assessed in comparison with Cyberglove®



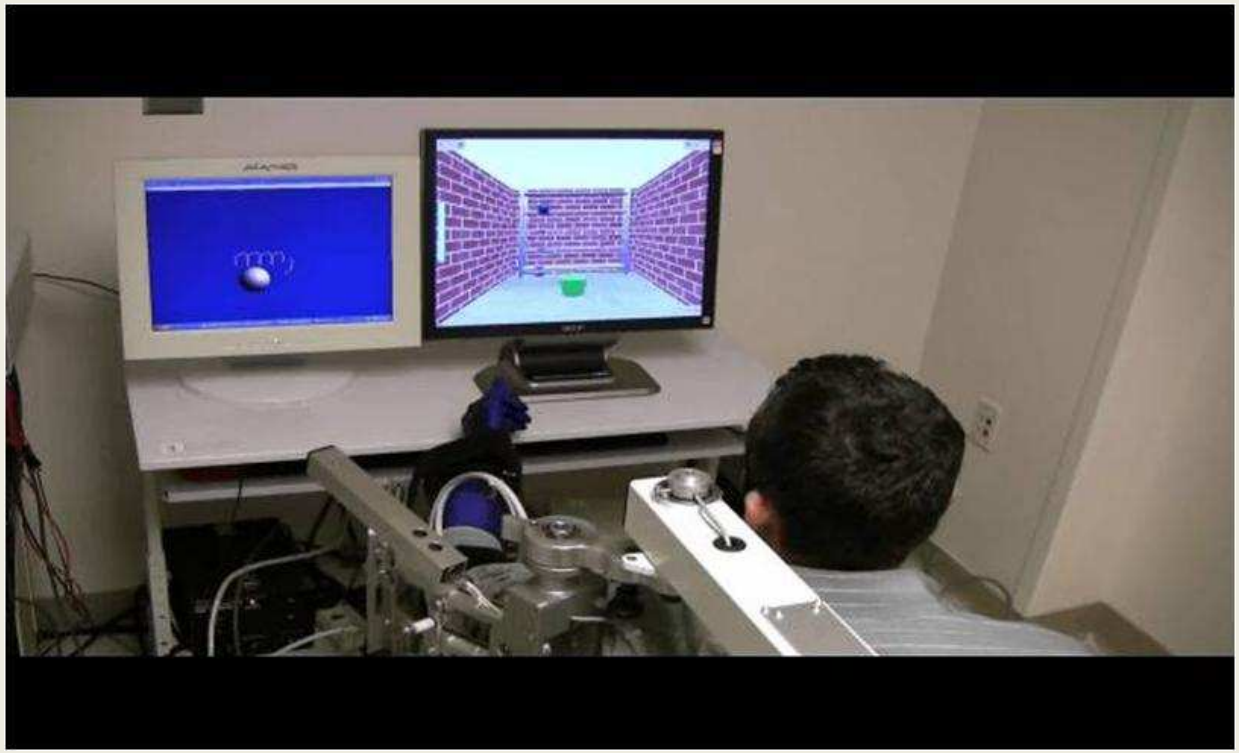
Dashed lines: CE sensing glove outputs.

Blue lines: Cyberglove outputs.

Robot Aided Rehabilitation (1)

real-time tracking of the hand kinematics – VR interaction
<u>therapeutic videogame-based system</u>

Manipulation of virtual objects



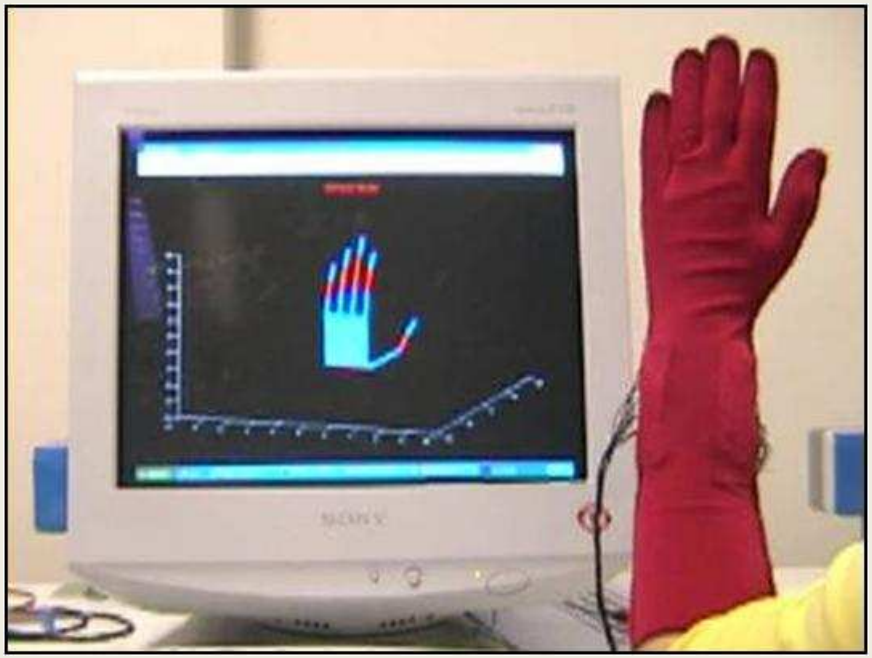
SPAULDING REHABILITATION HOSPITAL NETWORK

HST

Robot Aided Rehabilitation (2)

3D Hand model

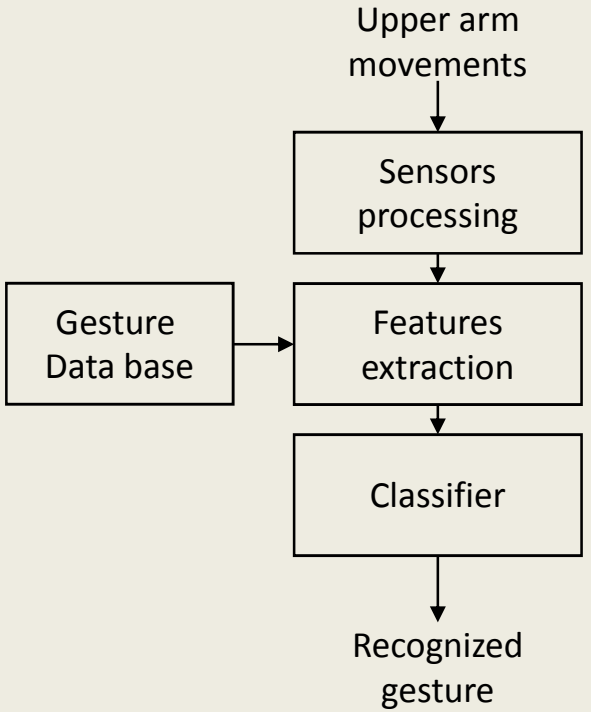
Hand model designed in order to show the capability of the sensorized glove in tracking hand **grasp and release** movements with an accuracy sufficient to provide visual feedback in near real-time.



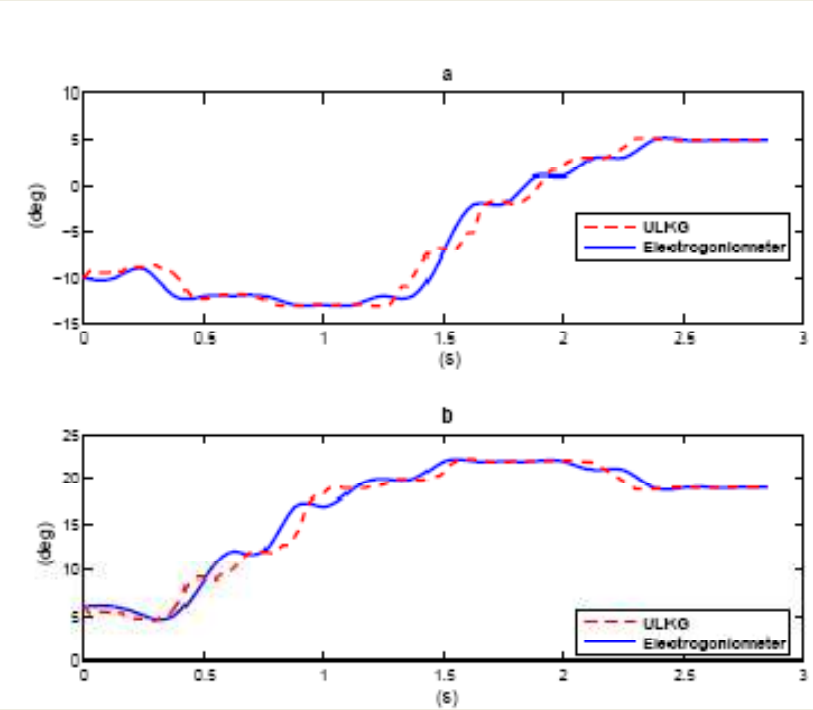
Subjects generally considered as satisfactory the near real-time animation of the 3D hand model controlled via the sensorized glove.

The sensing shirt (1)

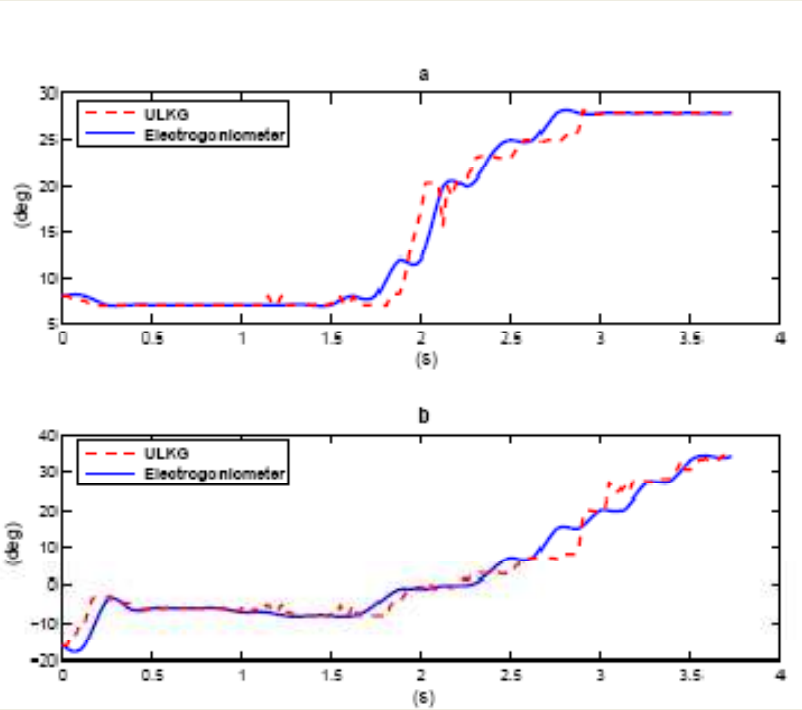
- Sensors characteristics
  - 29 piezoresistive sensors
  - distributed on all the upper limb joints
- Upper arm gesture classification
  - Calibration phase: a set of postures is registered.
  - User postures are recognized during the movement.



The sensing shirt (2)



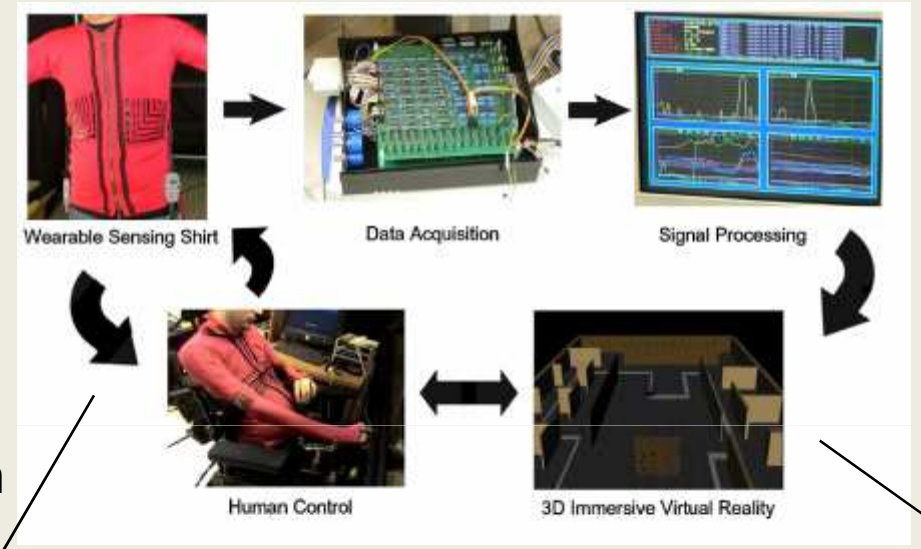
Flexion (a) and abduction (b) angles of the wrist.



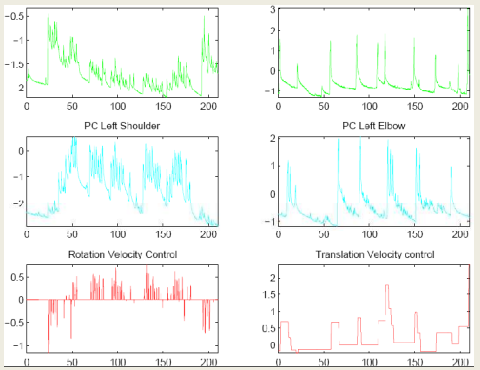
Extension (a) and flexion (b) angles of the shoulder.

Body Machine Interfacing (1)

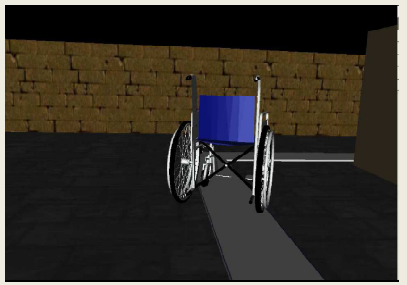
- Control strategy decision
- Calibration
- Wheelchair control



Calibration



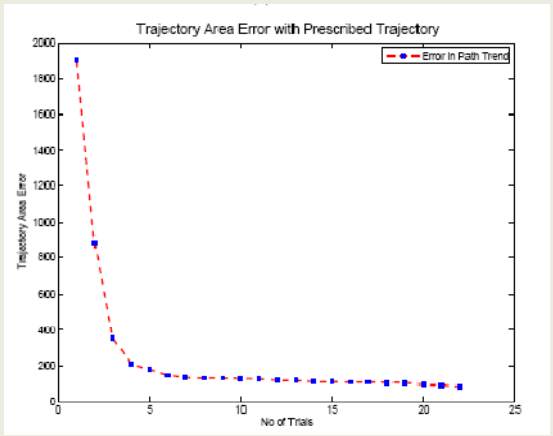
Wheelchair control



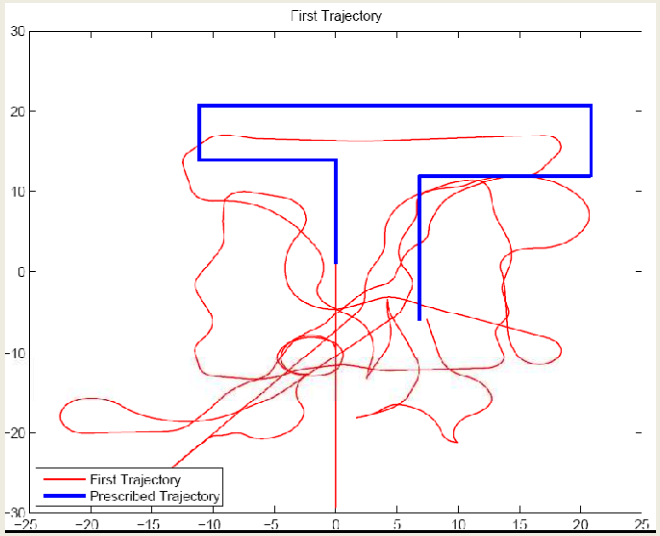
Body Machine Interfacing (2)

- Results
- The subject was asked to follow a reference path in the virtual environment
- The ability of subjects in following the reference trajectory has been evaluated
- An improvement of the ability with training has been observed

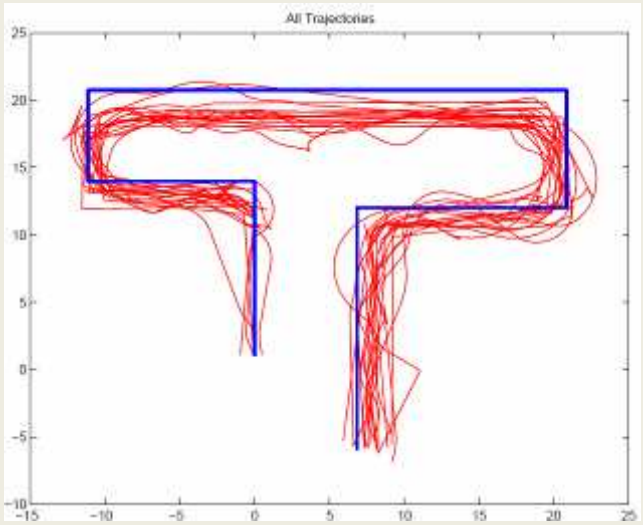
Error vs. trial N.



Explorative trial



Recorded trajectories



Alloderma aims

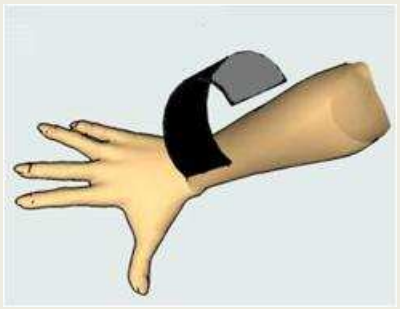
- Improvement of the existing technology toward industrial feasibility
  - Materials and production process
    - Sensors and fabric substrate
  - Electronics
  - Connections
- Applications
  - Design and ergonomics

Materials and production process

- New high-tech fabrics
  - Bi-elastic fabrics
    - Comfort, elasticity andl resistance
- Industrial production
  - Sensor materials
    - Solvent, Low resistivity
  - Screen-printing
    - Low viscosity
  - Alternative process
    - Inkjet with conductive inks
  - Multilayer
    - Improve insulation

Electronics

- Based on existing design
- New characteristics
  - Fully wearable
    - Wrist or arm worn
  - Inertial sensing
  - Realtime embedded software
  - Flexible connections



Applications: Design and ergonomics (1)

- Ergonomics for product evaluation

Applications: Design and ergonomics (2)

- Virtual prototyping