POLITECNICO MILANO 1863

2nd International Electronic Conference on Sensors and Applications
15–30 November 2015

Sensorized Garments for biomedical monitoring: Design issues

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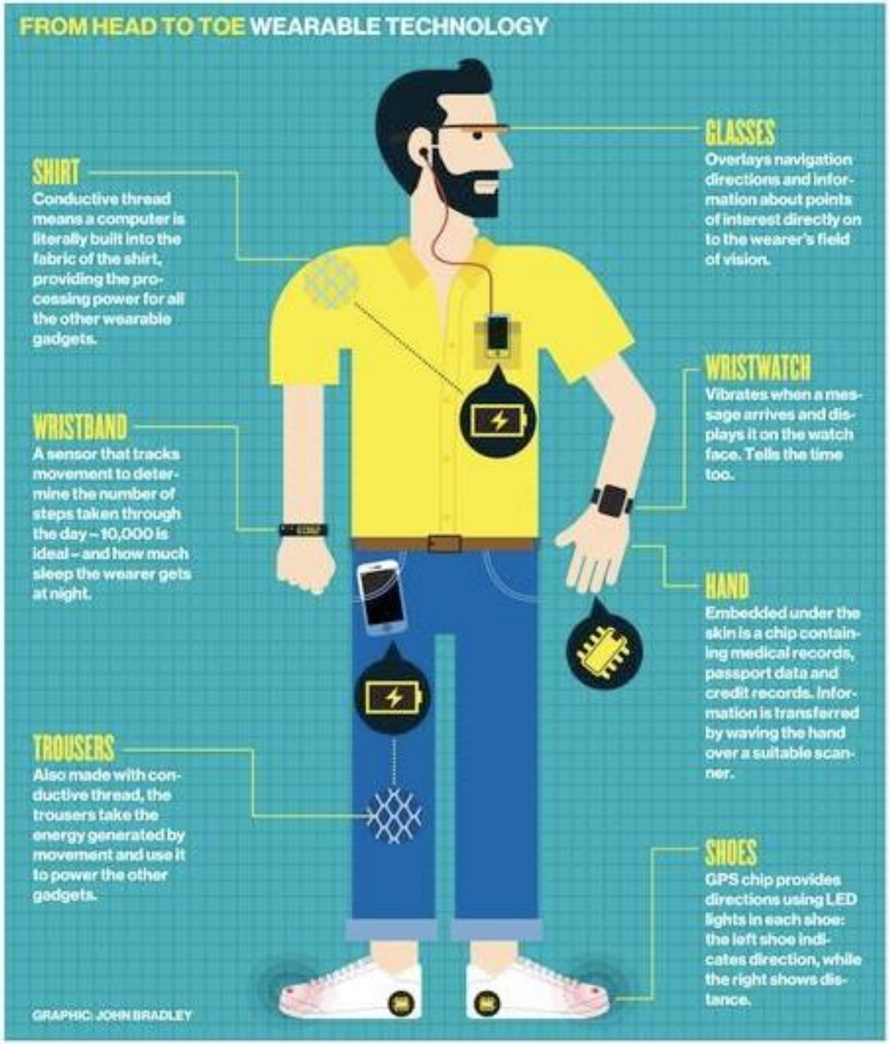
Introduction

2015-2025 decade: the “Wearable Era”

Wearable Health Systems (WHS) or Wearable Biomedical Systems (WBS) are integrated systems on body-worn platforms wrist-worn devices or even biomedical clothes, offering pervasive non-invasive solutions for continuous health status monitoring of biomedical, biochemical and physical measurements.



Main applications: Medicine, Life Style monitoring and Sport analysis (& fitness).

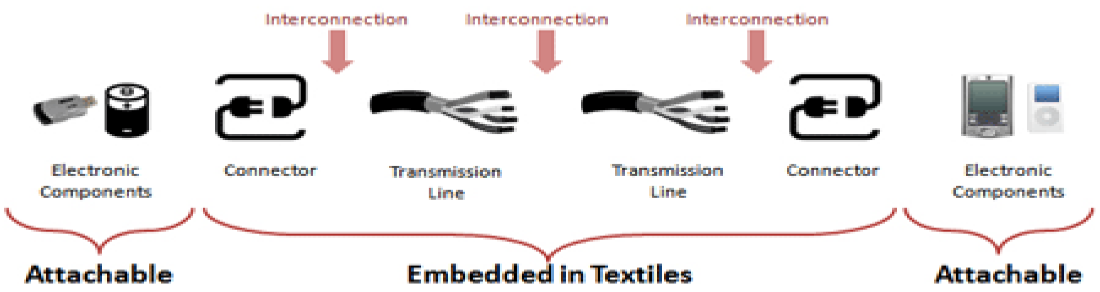
Introduction

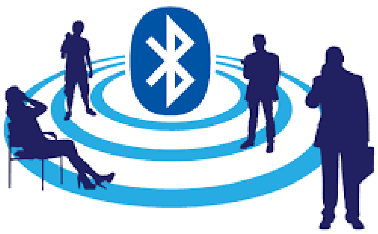
Generally it is thought that: making garments is very simple but for sensing garments, a great number of requirements are essentials:

<u>*Technological specifications:*</u> *sensors and actuators, materials, data communication (usually wireless), power supply and management, processing technique (onboard/on external devices, off line/real-time), algorithms for signal processing, …*

<u>*Physical and specifications:*</u> *connectors, elasticity and adherence of the supporting platform (garments or belts, or adhesive patch or other)*

<u>*Usability specifications:*</u> *GUI, washability and related stability of sensors, body positions and wearability (tasks, sensors, anthropometry…), elasticity and adherence of textiles, …*





Goal

This paper tries to discuss the most significant aspects to design a sensing wearable platform, in particular related to sensors for physiological signals monitoring.

Designing wearable systems

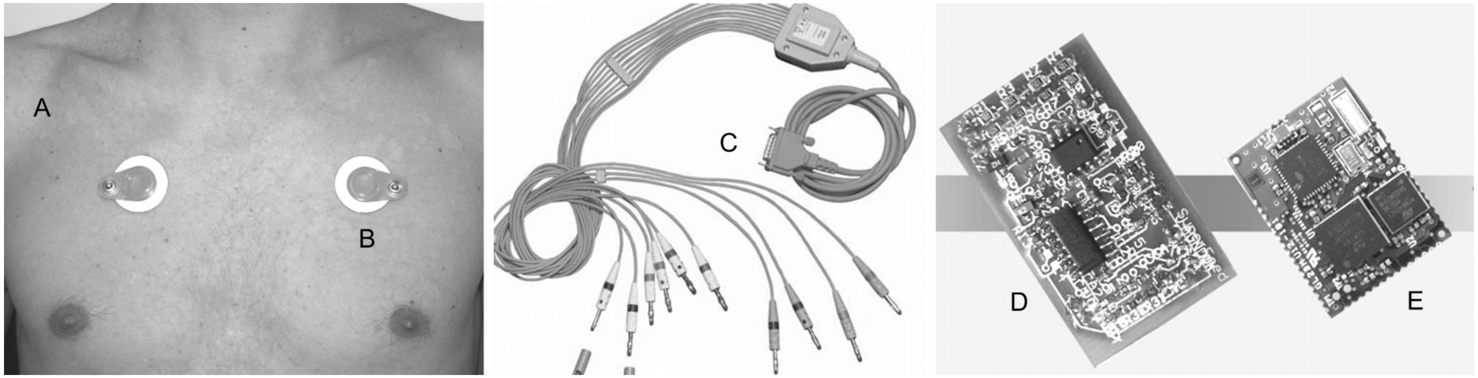
Two main specifications categories:

- ***Technological***: e.g. sensing principle and corresponding sensor implementation, materials and their properties, data transmission, power supply, processing and related algorithms;

- ***Design***: physical and design related factors such as anthropometry and gender issues, GUI, body positions and wearability, elasticity and adherence of the body fixing element or of the garments.

Method: measuring body signals

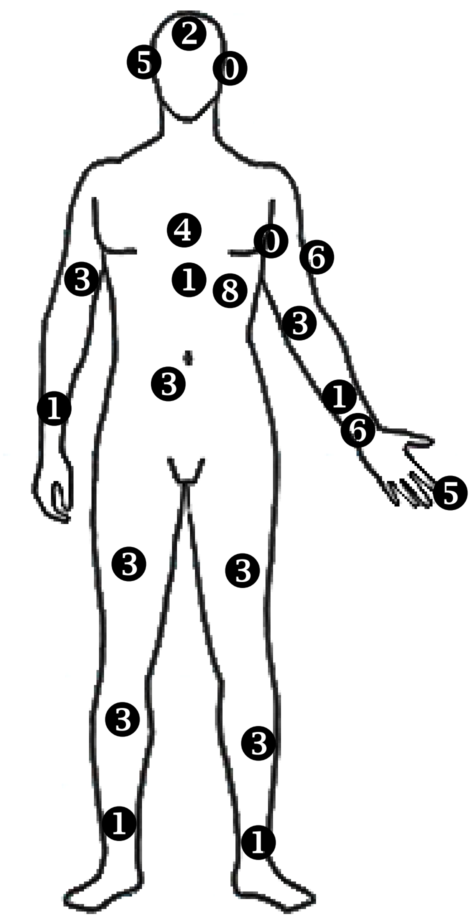
WBS are an ideal platform for multi-parametric non-intrusive monitoring of health status, thus providing a remote primary and secondary prevention. They implement the following chain.



Human as source of information (A), sensors (B) and their link (C) to measuring devices (D) and wireless data transmission (E).

Methods: measuring body signals

What, where, how …



No.	Signal	Sensor	Parameters	Typology
0	temperature	piezoresistive	Temperature	Hardware Probe (thermistor)
1	ECG (ElectroCardioGram)	electrode	Electrical heart activity, Heart Rate	Adhesive, textile, plate
2	EEG (ElectroEncephaloGram)	electrode	Electrical Brain activity	Plate; textile prototypes
3	EMG (ElectroMyoGram)	electrode	Electrical muscle activity	Adhesive; textile prototypes
4	Respiration	Strain gauge; Electrode for Impedance measure	Breathing rate, Volumes, respiratory times	Hardware probe, Adhesive, textile sensor
5	Blood gas	LED/optical	SpO2, CO2, Heart rate	Hardware Probe, POF for signal transmission
6	Blood Pressure	Cuff	Systolic/diastolic values, Heart rate	Hardware System
7	Interface pressure	Piezoresistive; capacitive	Contact pressure	Piezoresistive ink, capacitive sensor both electric and textile
8	Resistance	Electrodes for Impedance measure	GSR, Body impedance	Hardware System

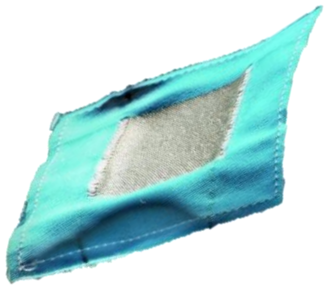
All of these measures requires the sensor to be closely and firmly in contact with the body and without moving over the skin to avoid artefacts.

Note. Movement is measured with miniaturized hardware system applied to each body district.

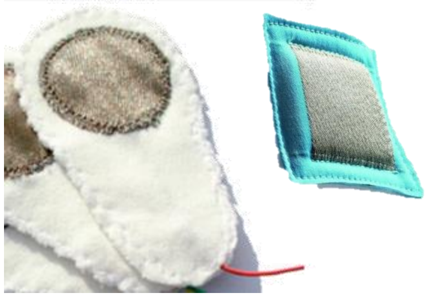
Methods: measuring body signals
bioelectric signals: electrodes

For bioelectric signals (e.g. ECG, EMG, and EEG) , sensors are electrodes.

- The traditional adhesive Ag/AgCl electrodes placed directly onto the body in specific positions and with a connecting snap.



- Textile electrodes (or Textrodes) belong to the polarized electrodes class; they are a textile structure constituted of electrically conductive yarns which may be used in direct contact with the skin.
- Textrodes are made of textile yarns with electrical properties:
    - a) Metal yarns, i.e. yarns containing conductive fibers (stainless steel, copper or silver mixed with natural or synthetic fibers);
    - b) Yarns containing electro-conductive fibers (polymeric or carbon coated threads).



Advantages: non-irritating the sking, embedded into standard clothes.

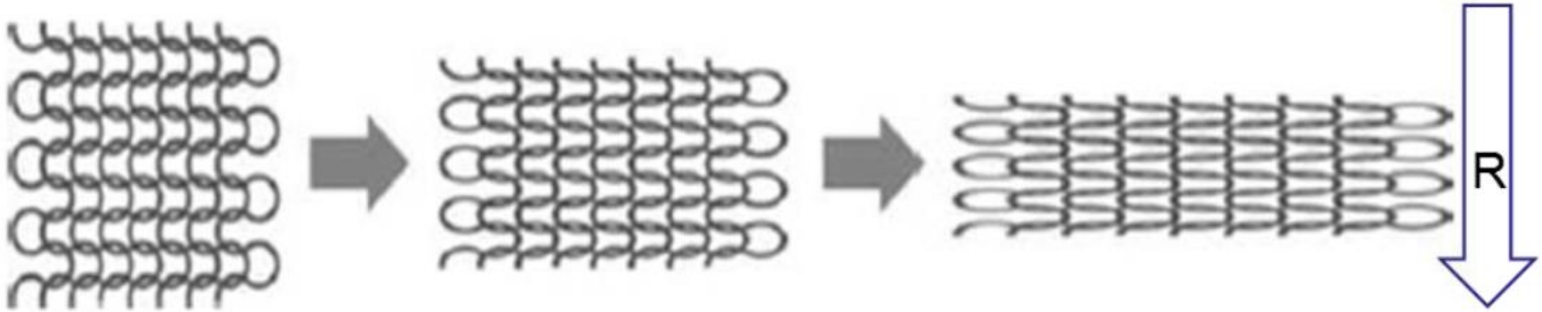
Disadvantage is the poor skin/electrode contact.

Methods: measuring body signals
bioelectric signals: electrodes

Material for Textrodes

Material	*Merits*	*Demerits*
Conductive rubber	High conductivity, easy to shape, cheap	Poor flexibility and permeability to air and liquid
Silver-coated polymer foam	High conductivity, easy to shape, flexible, antibacterial	Poor washability and permeability to air and liquid, possible oxidation
Metal-coated or sputtered fabrics	High conductivity, fabric material	Poor washability, possible oxidation
Woven metal fabric	Controlled conductivity, fabric material	Difficult to handle, skin irritation, low elasticity
Woven conductive polymer fabric	Fabric material, elasticity	Low conductivity
Carbon yarns	High mechanical resistance, high thermal insulation	Average conductivity, skin irritation, low elasticity
Stainless steel yarns	High conductivity, no skin interaction	Low elasticity, high weight

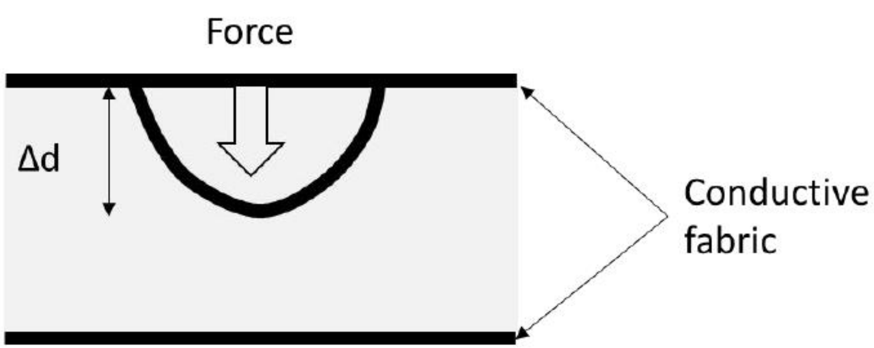
Methods: measuring body signals
textile strain gage and force sensor implementation



A strain gage exhibits a percent change in resistance that is directly proportional to the strain applied.

Strain = dL/L $R/R=S_g*Strain$

Gage factor= S_g is the coefficient to convert strain to dR/R



Dielectric substance: capacitance ⇧

Piezoresistive substance: Resistance ⇩

Capacitive textile sensor

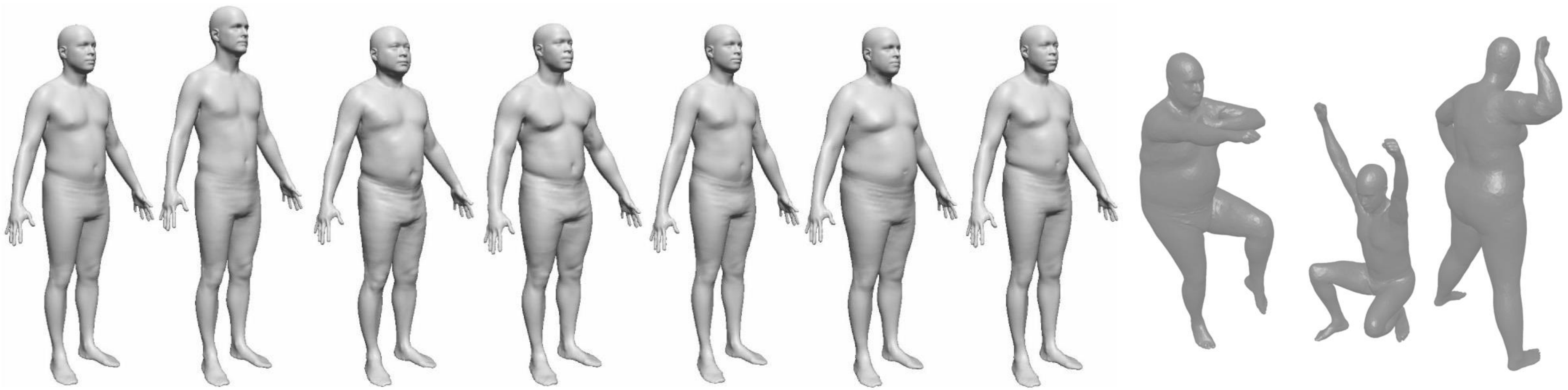
Method: Designing sensorized garments

Anthropometry is the discipline dealing with the measurement of physical features of the human body and their differences related to age, gender, lifestyle and ethnicity as inter-subject variability factors, or even time (from circadian to long period) and external environment as intra-subjective factors.

Designing garments for man and woman have obvious different requirements for shape and fit not only for their different dimension but also for the daily task the users have to do.

Basic Design criterion: «**Several Sizes**»

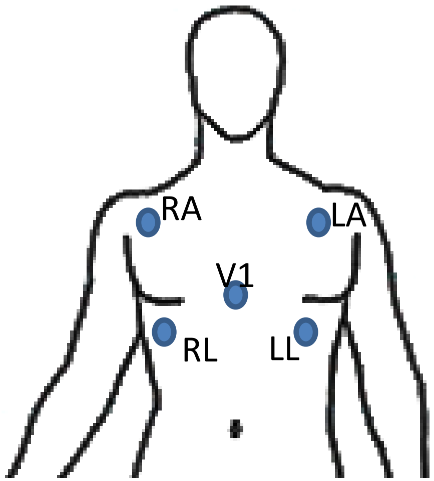
Various sizes of a product are required to fit to the entire range of population. This is generally required for devices or personal items, which must conform more closely to the body as clothing.



Method: Designing sensorized garments

Design issues:

- Specific and modulated elasticity along the different part of the garment is needed to assure a good sensor-skin contact. Because of the intrinsic weakness of the bio-potentials measurable at the skin (0.5 – 2 mV), a close contact between electrodes and skin is of major importance. It also minimize the movements of sensors over the skin during the recording to obtain a stable high quality signal .
- For example to record the electrical activity of the heart, the elasticity of the garment should implement a close fitting of the suit around the thorax.
- Modulated elasticity is obtained by proper choice of elastic yarns and/or by design, and they determine also comfort and wearability of the garments itself.
- Wearability is crucial for weak users for autonomous operations, and repeatable sensors inter-session repositioning to achieve a reliable monitoring.



Design guidelines

Gemperle et al. analyzed the wearability requirements for hardware systems that have been formalized in a 13-points guideline

Guidelines for Wearability:

1. Placement (where on the body it should go)
2. Form Language (defining the shape)
3. Human Movement (consider the dynamic structure)
4. Proxemics (human perception of space)
5. Sizing (for body size diversity)
6. Attachment (fixing forms to the body)

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7. Containment (considering what's inside the form)
8. Weight (as its spread across the human body)
9. Accessibility (physical access to the forms)
10. Sensory Interaction (for passive or active input)
11. Thermal (issues of heat next to the body)
12. Aesthetics (perceptual appropriateness)
13. Long-term Use (effects on the body and mind)

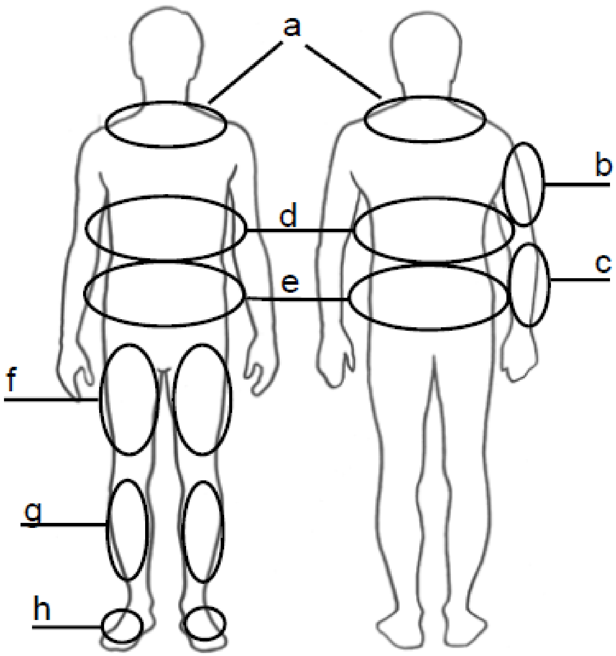
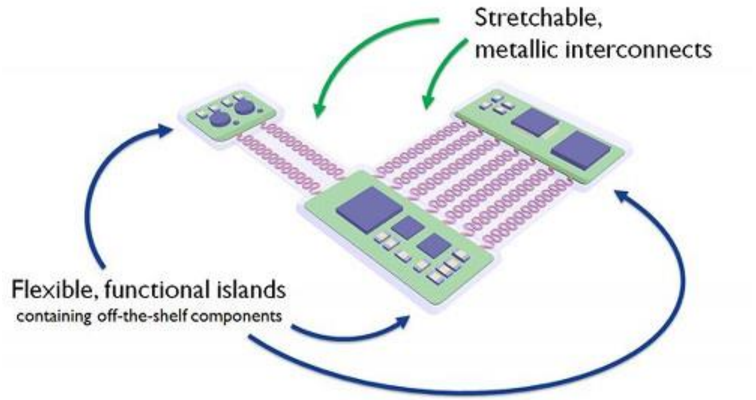


Fig. 1, The general areas we have found to be the most unobtrusive for wearable objects are: (a) collar area, (b) rear of the upper arm, (c) forearm, (d)rear, side, and front ribcage, (e) waist and hips, (f) thigh, (g) shin, and (h) top of the foot.

Conclusions

WBS are an ideal platform for multi-parametric non-intrusive monitoring of health status, thus providing a remote primary and secondary prevention. In this paper we have presented some issues related to the design of these systems with specific reference to technological and human factors requirements.

One critical issue that it is under research and development is the integration of textile with flexible electronics for a complete embedded system.



This allows to match the methodological approach pursued by wearable systems: non intrusiveness, i.e. a process that does not affect user behavior and is completely transparent to him/her during his/her own daily activities. Only in this case we will obtain actual wearable 2.0 generation system for our health.

Thank you

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