Interactions Humain/Textile/Environnement à l'Ere Digitale

By Xianyi Zeng
ENSAIT Textile Institute, Roubaix, France

Séminaire sur l'hybridation de la matière avec le digital – 13/06/2019 (Ecole Polytechnique)

Outline of the presentation

- **Basic information and main research activities**
- **Smart materials**
- **Textile sensors and actuators**
- **Intelligent clothing: electronic and textile integration process**
- **E-garments and human big data**
- **Two applications of intelligent wearable systems:**

- Fetal movement and pregnant woman's well-being detection

- Human/robot interaction for risk management (firemen's clothing)

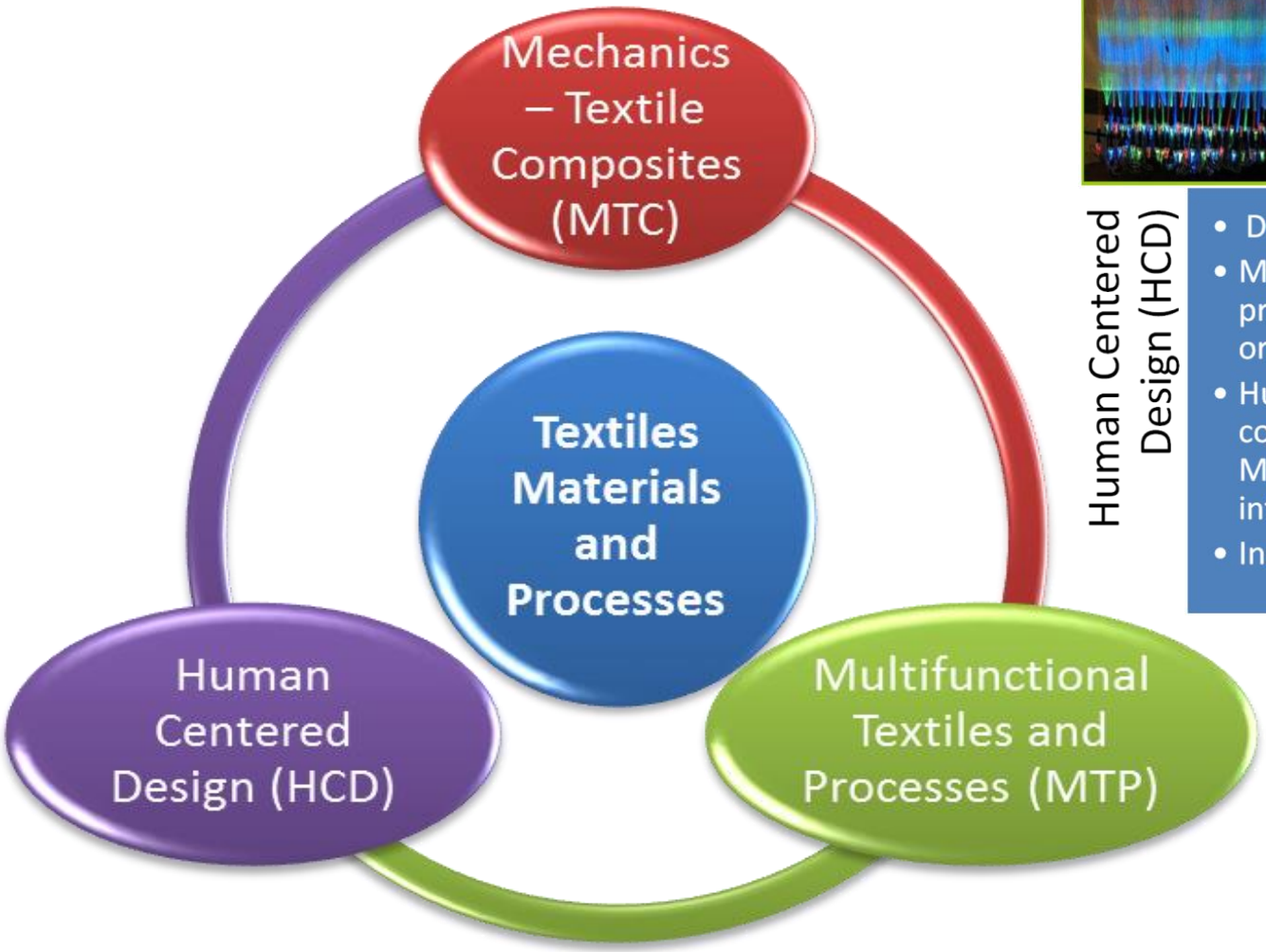
ENSAIT: the unique French textile engineer school

Location: Roubaix city - Lille Urban Community

GEMTEX Research Laboratory

Human Centered Design (HCD)

- Decision support system
- Modelling and optimization of products, processes and organizational systems
- Human factors: perception, cognition and Man/Material/environment interactions
- Instrumentation and Control



A multidisciplinary laboratory: chemistry, mechanics and IT
two intergroup themes: smart textiles and sustainable textiles

Research staff in 2017/2018

Permanent researchers/teachers:

- 10 teachers from ENSAIT (PhD holders in IT)

Non-permanent researchers:

- 23 PhD students in progress
- 6 PhD students defended their thesis
- 2 Post-Doc researchers

HCD Research Team

Research results in HCD (2017/2018)

- **Journal papers with IF: 30**
- **Chapters in scientific books: 6**
- **Patents: 3**
- **Industrial contracts (>10):**

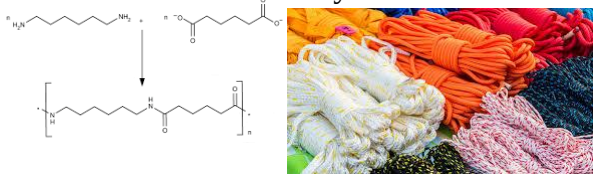
  France Télécom, Orange, CHRU, Unilever, Decathlon, Damart, Adidas, Chanel, …
- **European and national projects:**

  SMDTex (EU Erasmus Mundus), ETEXWELD (EU H2020) FBD_BModel (EU H2020), HOMO Tetilus (FR ANR), IOTFetMov (FR ANR), Camille 3D Sensoriel (FR FUI), DIGITEX2 (FR FUI), SUCRé (RE ARCIR) …

Fashion/Textile Industry 4.0

History of the textile industrial revolutions:

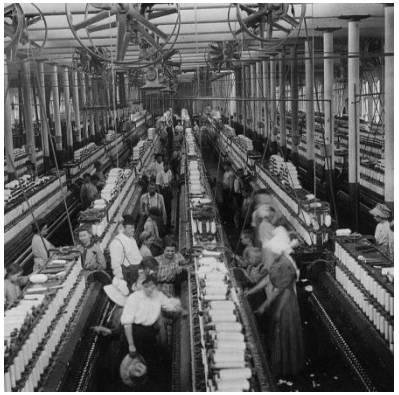
End of the 19th century: first **chemical** fiber



1784: first mechanical loom

Steam-powered **mechanical** manufacturing

End of the 19th century: first textile production

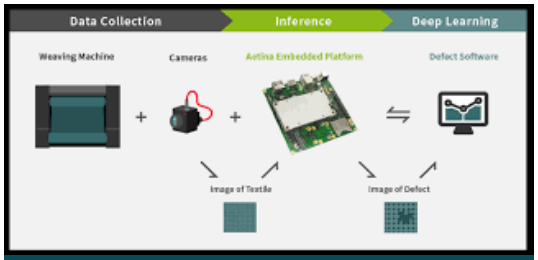


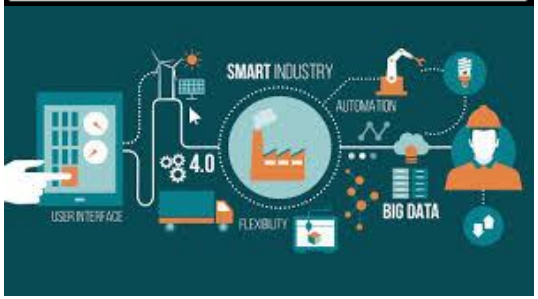
Electricity-powered mass production

1970s: first programmable textile

Automation of manufacturing by **computers**

Today: big data driven, smart factory, tracking, deep learning





Cyber-physical systems

Combination of ICT and materials

End of 18th -19th century | Beginning of 20th century | 1970s | Today

Smart Materials

Artificial intelligence – create decision on the base of external stimuli

Intelligent structures – reaction to external stimuli

- "Intelligent" body adaptive response apparel textiles having improved comfort controlled by the state of microclimate and wearers needs.
- "Intelligent"-knowledge based technical textiles with specified properties (e.g. locally compressive behaviour) and complex actions (comfort type mattresses for disabled persons, intelligent car seats etc.)
- Hybrid multifunctional textiles for protective clothing combining improved protection (a barrier against the selected types of radiation and particles) with improved comfort.

Smart Materials

Stimulus (change) S => sensors

Electromagnetic energy (UV, visible, IR radiation)

Chemical energy (moisture, presence of ions, etc.)

Mechanical energy (pressure, break, twist, atd.)

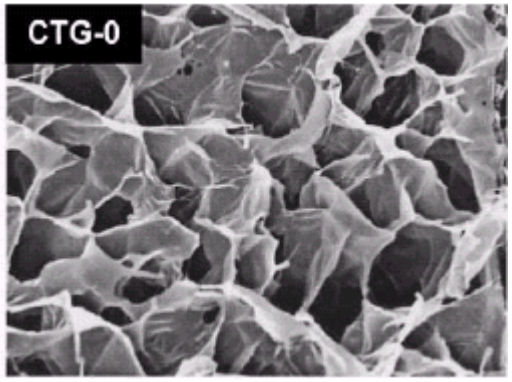
Response (change..) R => actuators

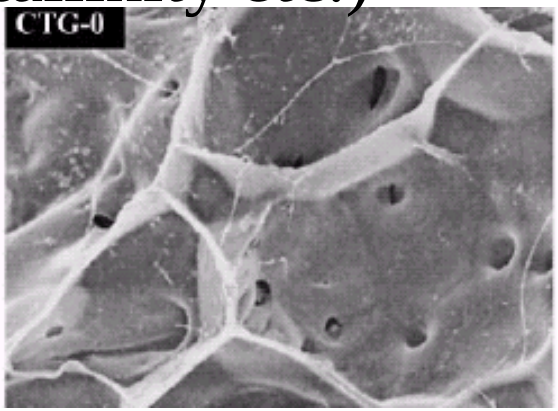
Shape (swelling, shrinking)

Colour (shade, intensity)

Electrical conductivity

State of matter (phase change, crystallinity etc.)





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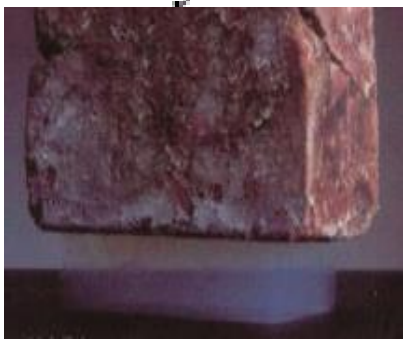
Smart structures

- Synthesize new materials and structures at the atomic or molecular level with smart functionality
  - New discoveries are required
  - Technologies are immature

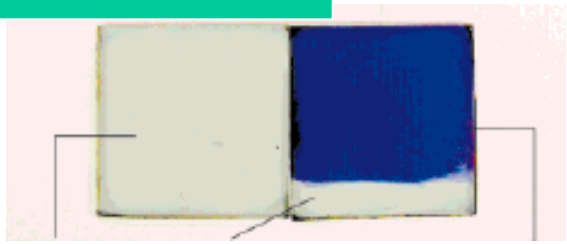


- Synthesize new materials and structures by compositing known constituents
  - Active elements attached to the structure (parasitic)
  - Active elements embedded in the structure

Smart Materials

Active and passive smart textiles: reversible

electrochromic

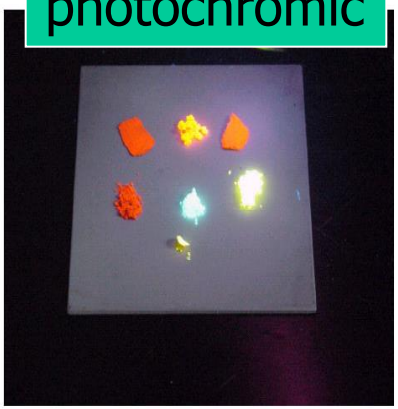


oxidation reduction

- Sensitive to external fields (ph, radiation, electric, magnetic, mechanical fields). PASSIVE
- Changing properties (usually form) as response to external field changes ACTIVE

diabetes

photochromic

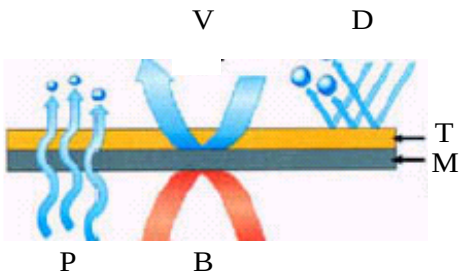


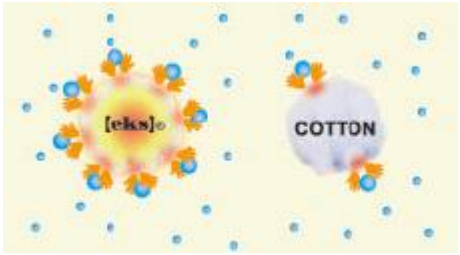
Active smart textiles

- Shape memory

(reversible form changes due to heating and cooling)

- Heat storing and evolving materials
- Variable porosity and water vapor permeability

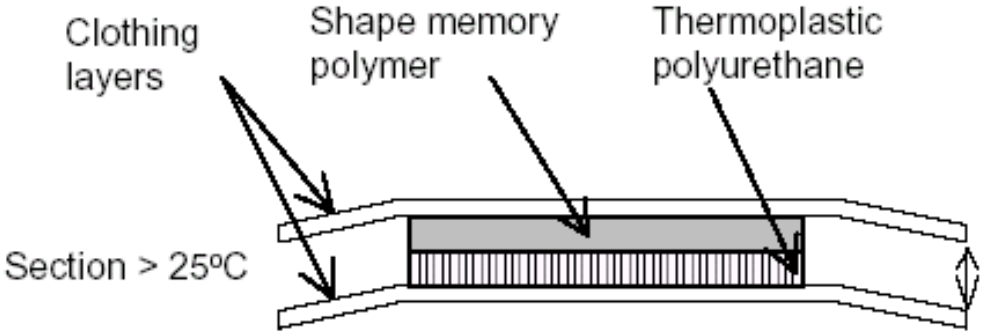


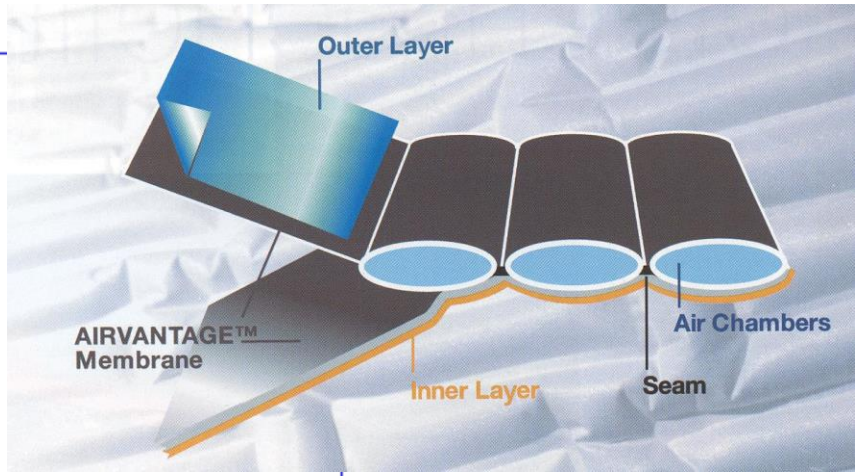


Smart Materials

Thermal insulation

Material	Thermal Resistance $(Km^2/w)/mm$
Polyester (hollofill)	0.0151
Polyester (microfibres)	0.0320
Polyester (split-fibres)	0.0473





Categories of sensors and actuators:

- Optical (Sensor and actuator)
- Electrodes – biopotential (sensor and actuator)
- Force/pressure/stretch (sensor and actuator)
- Temperature (sensor)
- GPS (sensor)
- Chemical and gas (sensor)
- Microphones (actuator)

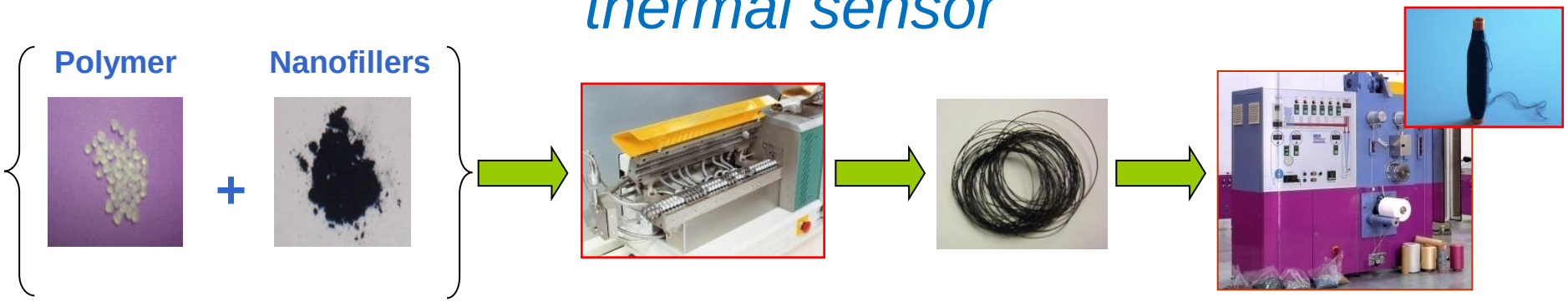
Textile materials for sensing and actuation:

- Fiber functionalization
- Fabric surface functionalization
- Fabric structure change

Textile Sensors and actuators

Fiber functionalization with nanotechnology:

incorporation of nanofillers for functional properties => thermal sensor



- Dispersion of nanofillers
- Characterization of physicochemical properties of polymers
- Thermal and rheological behavior

Functional fibers

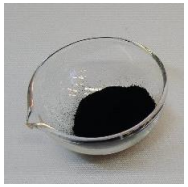
Thermal sensors

Textile Sensors and actuators

Functionalization of textile surface

Instrumentation of parachute to monitor inflation → elongation piezoresistive sensor (change of electrical conductivity)

Carbon black



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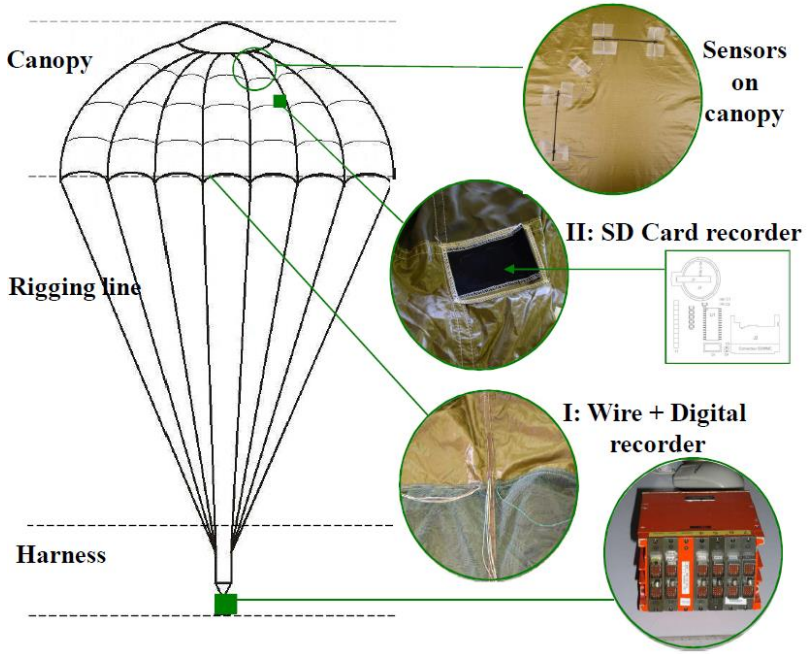
Thermoplastic elastomer

Conductive polymer composite by solvent process

Sensor on polyamide 66 fabric

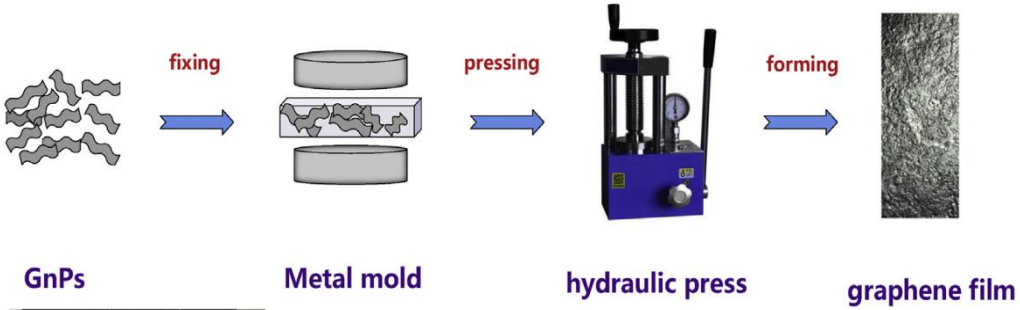


Elaboration by **solvent deposition** of conductive track whose electrical conductivity varies with external stress.

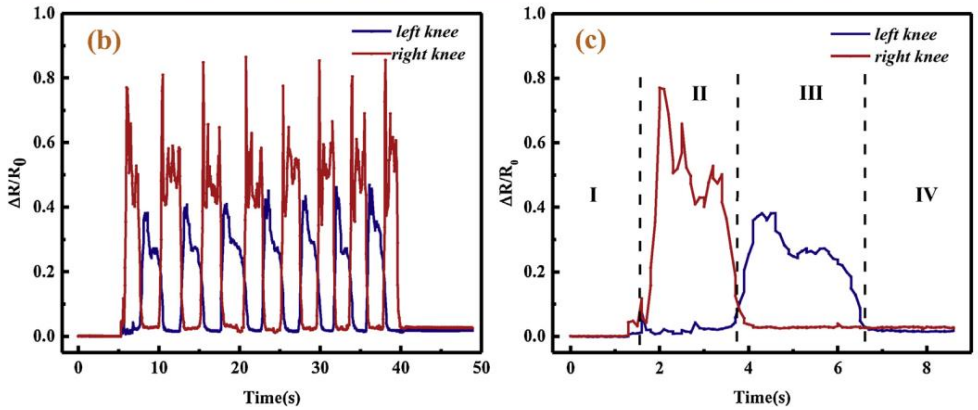
Textile Sensors and actuators

Wearable graphene film strain sensors encapsulated with nylon fabric => mechanical strain sensor

Graphene: crystalized bi-dimensional material



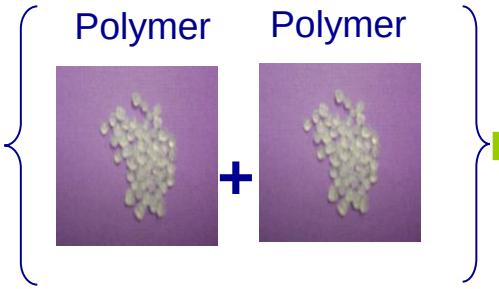
A flexible and high conductivity graphene film is fabricated by thermal expansion-pressing forming process



Human motion monitoring

Smart Materials: Textile Sensors and actuators

Formulation of mixed immiscible polymers for defined morphologies



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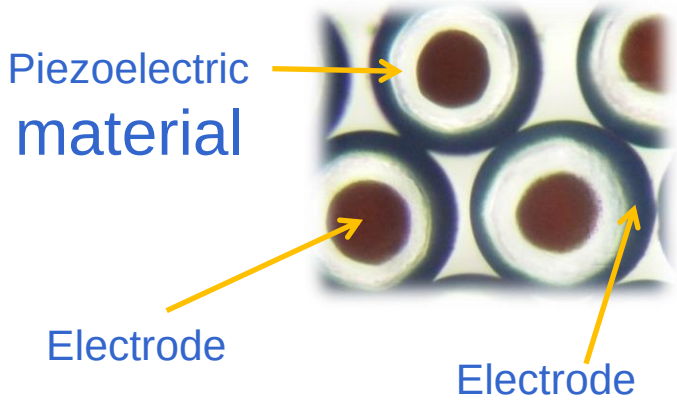
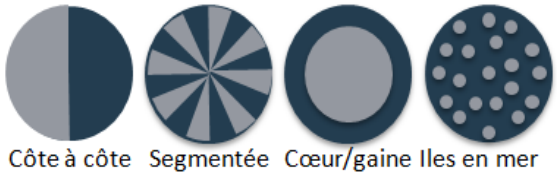
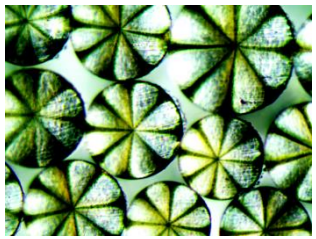
Development of tricomponent piezoelectric polymer fibers for energy harvesting textiles

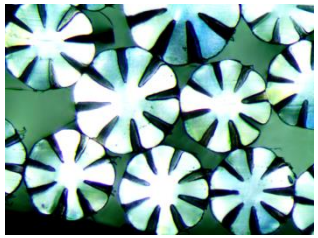


Tricomponent Melt



Nanofibres





Ultra fine fibre for air filtration

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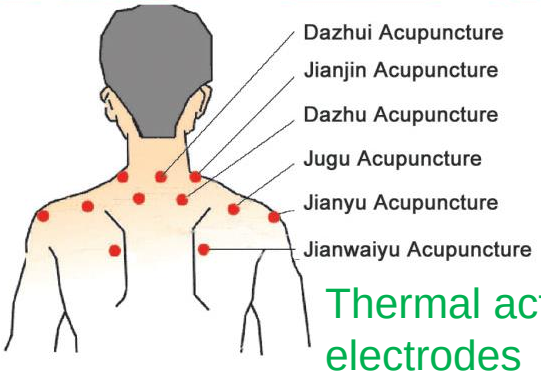
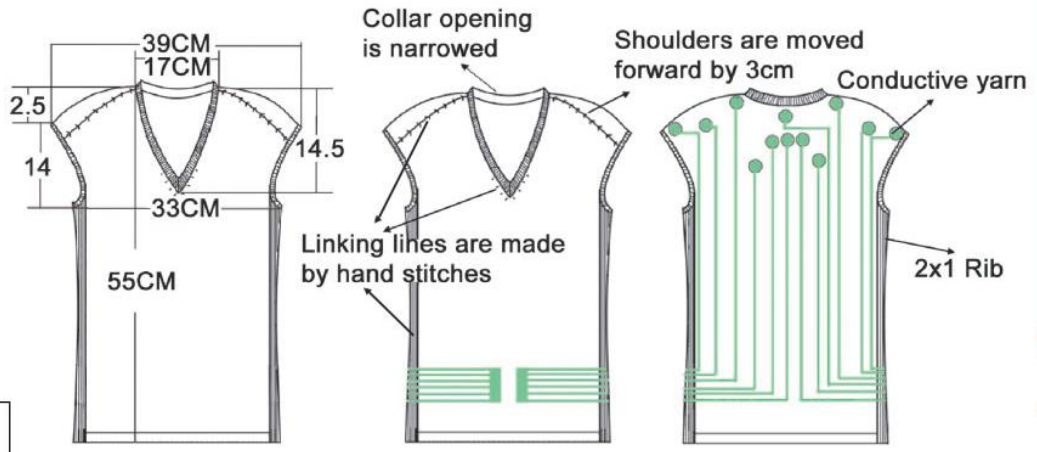
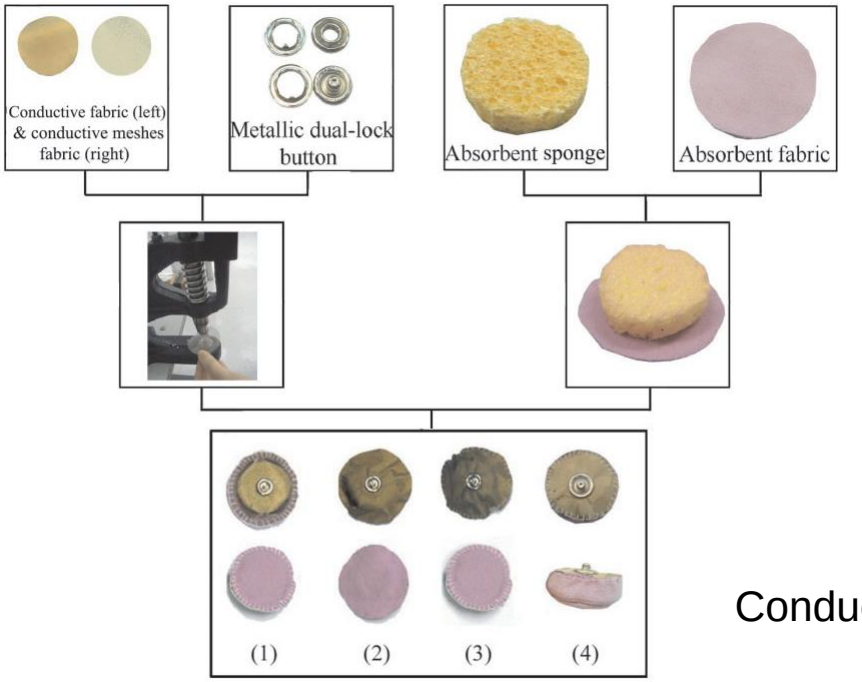
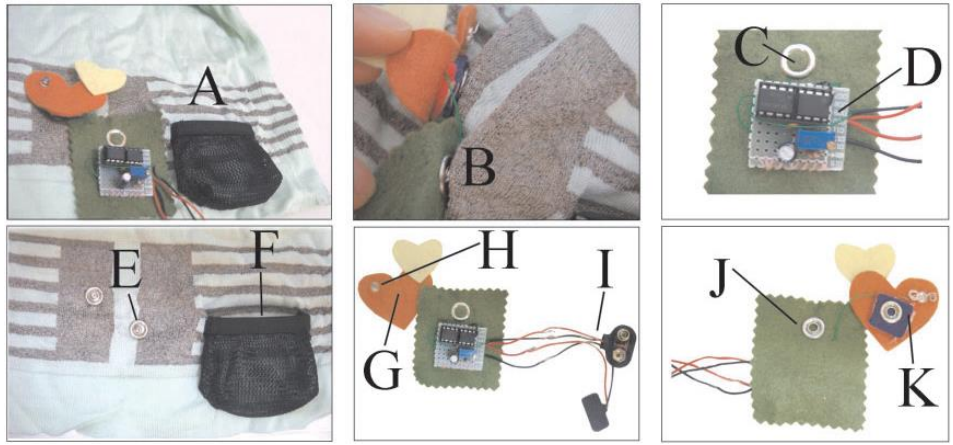
Fabric thermal actuation: transcutaneous electrical nerve stimulation => knitwear design



Thermal actuation from electrodes







Conductive and absorbent fabrics for textile electrodes

Intelligent clothing: electronic and textile integration process

Wearable electronics

E-TAG AND SWEATER SNAP CONNECTIONS

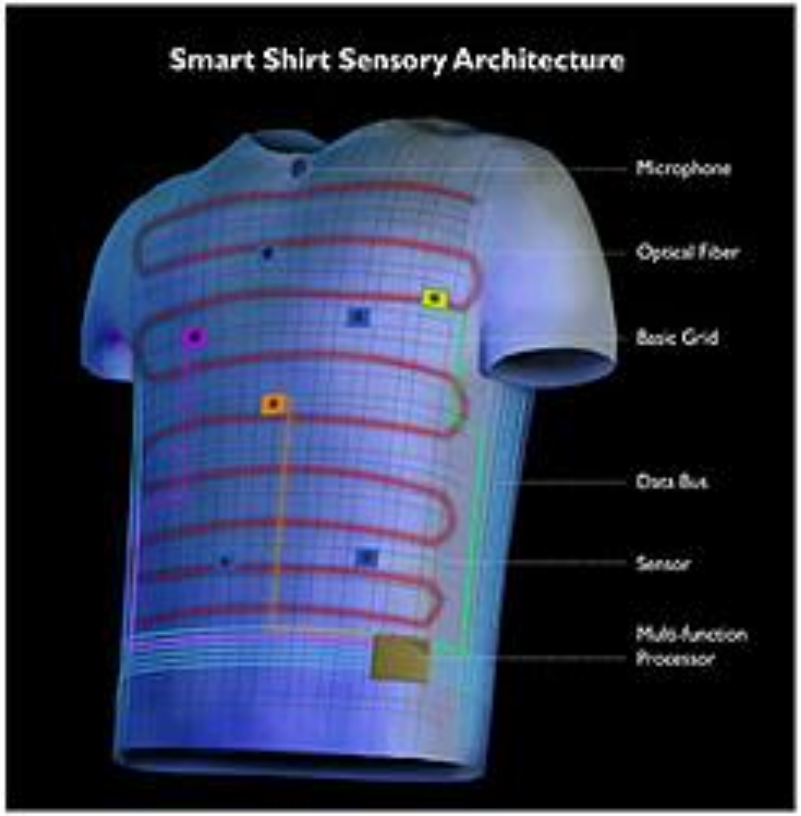
Music jacket

Intelligent clothing: electronic and textile integration process

Inteligent shirt

- Electronic devices
- Heart rate
- Breathing
- Body temperature
- Electrocardiogram
- Voice

Weave with optical fibers net



Intelligent clothing: electronic and textile integration process

Applications: permanent human data monitoring, collection and learning

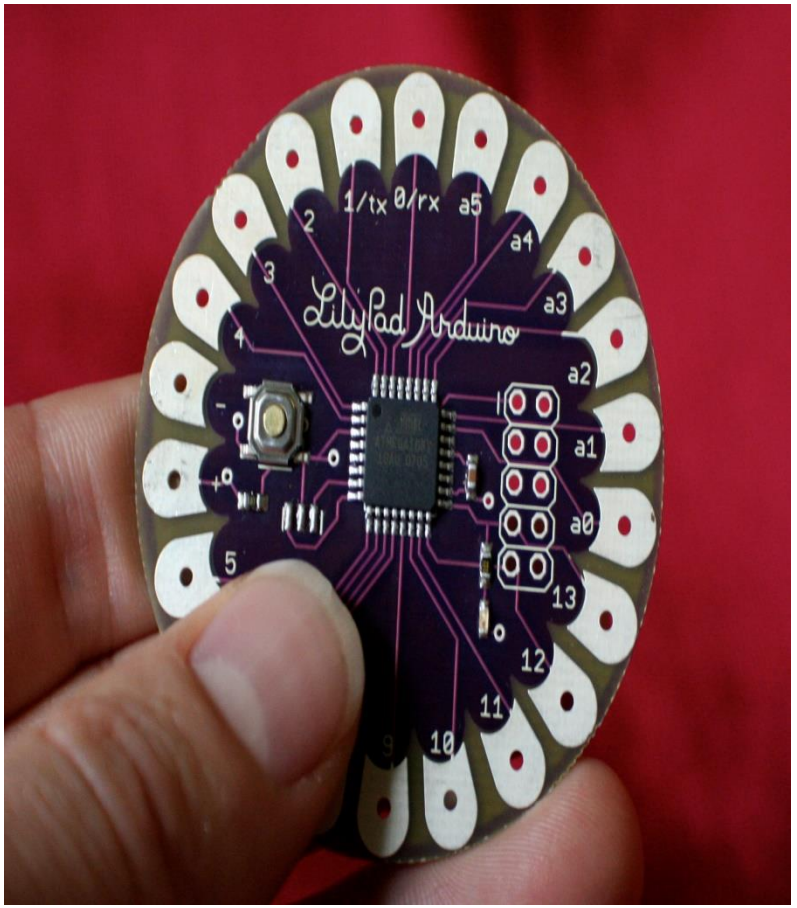
- Fashion design
- Medical diagnosis
- Security, protection and risk management
- Sport
- Human cooperation

2007 - One hundred eleven

Wearable system: basic components – micro controller

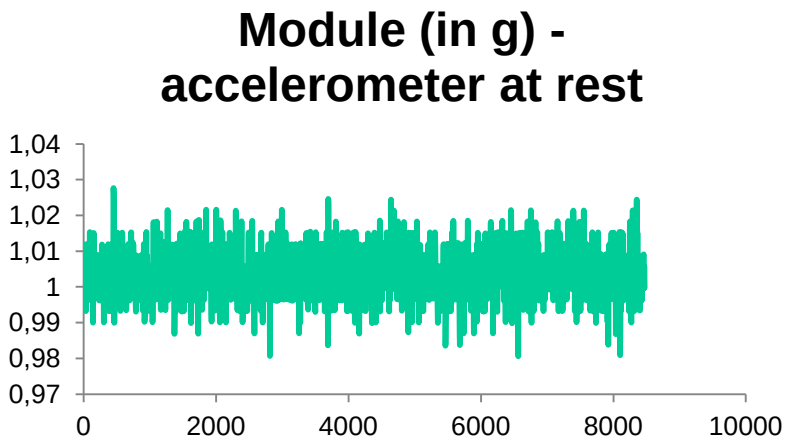
LilyPad Arduino

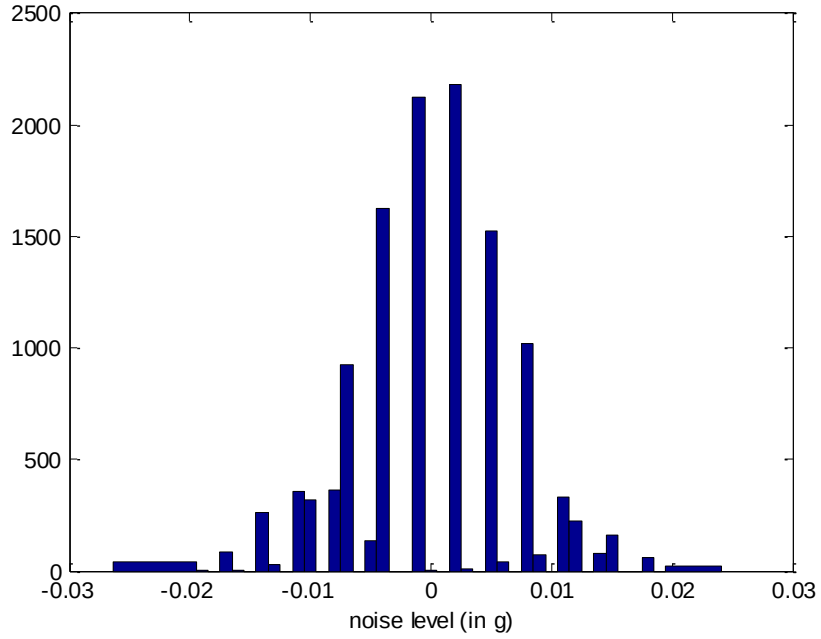
- A microcontroller board for e-textiles, sewed to fabrics and mounted power suppliers, sensors and actuators
- Programming with the Arduino software
- Small size: a circle of 50mm in diameter
- Washable



Intelligent clothing: electronic and textile integration process

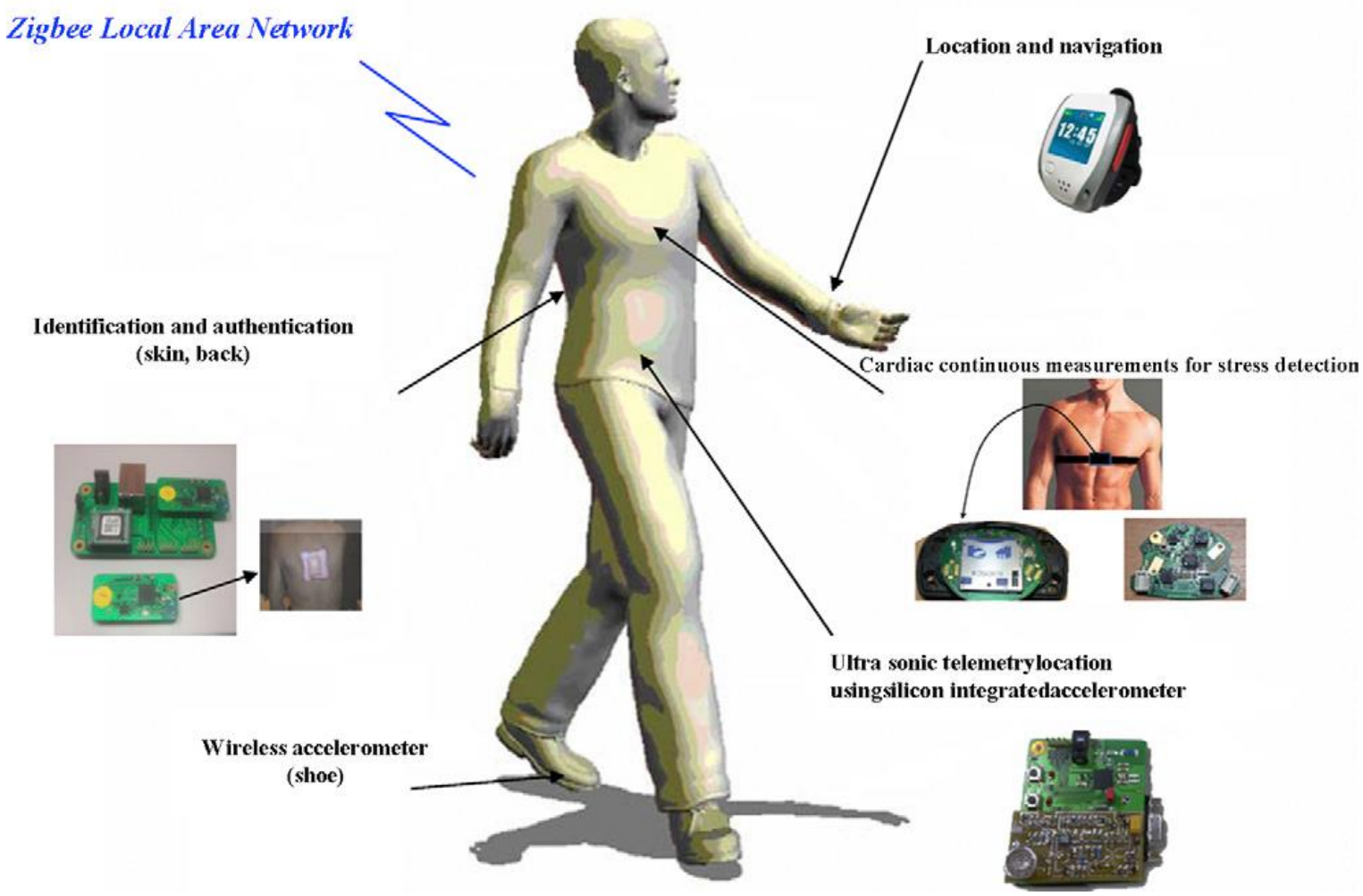
Wearable system: basic components – sensors





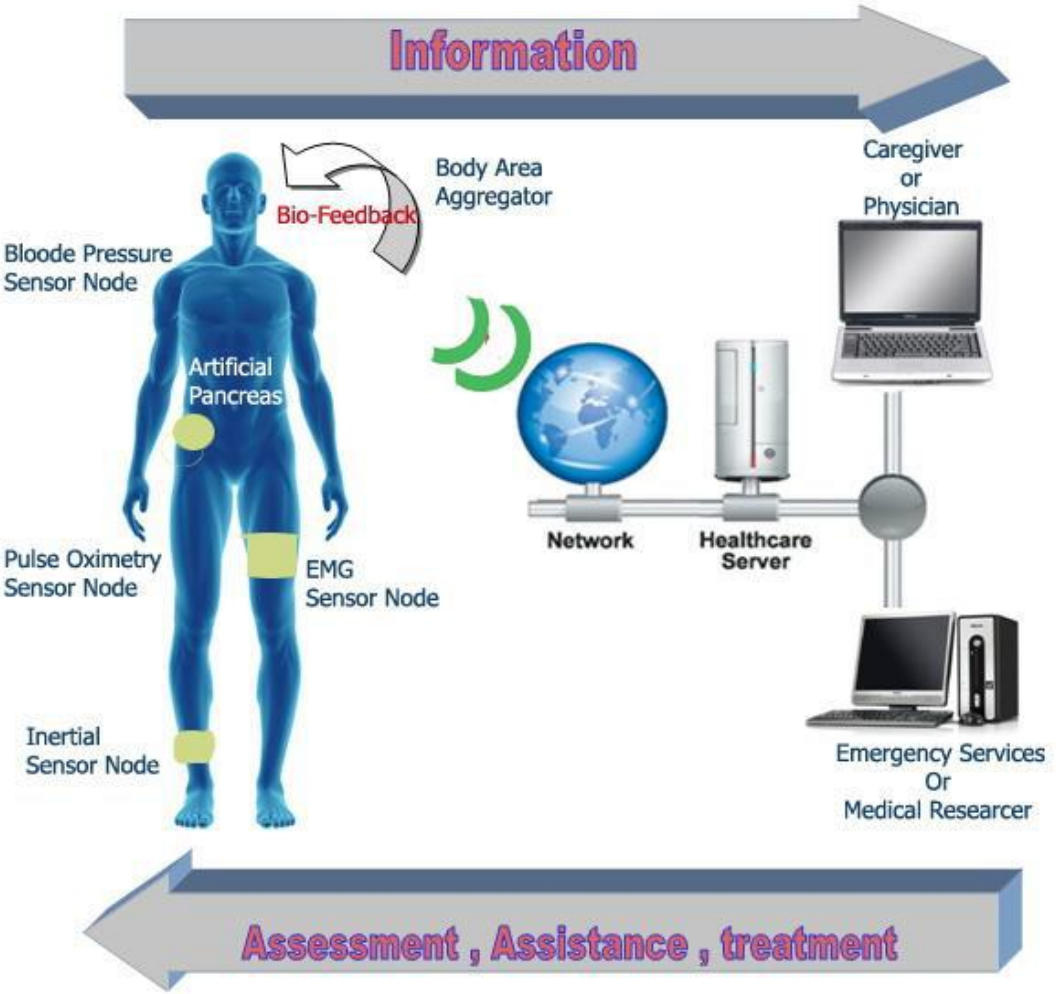
Intelligent clothing: electronic and textile integration process

Intelligent garment for monitoring health state



Intelligent clothing: electronic and textile integration process

Intelligent garment for remote diagnosis



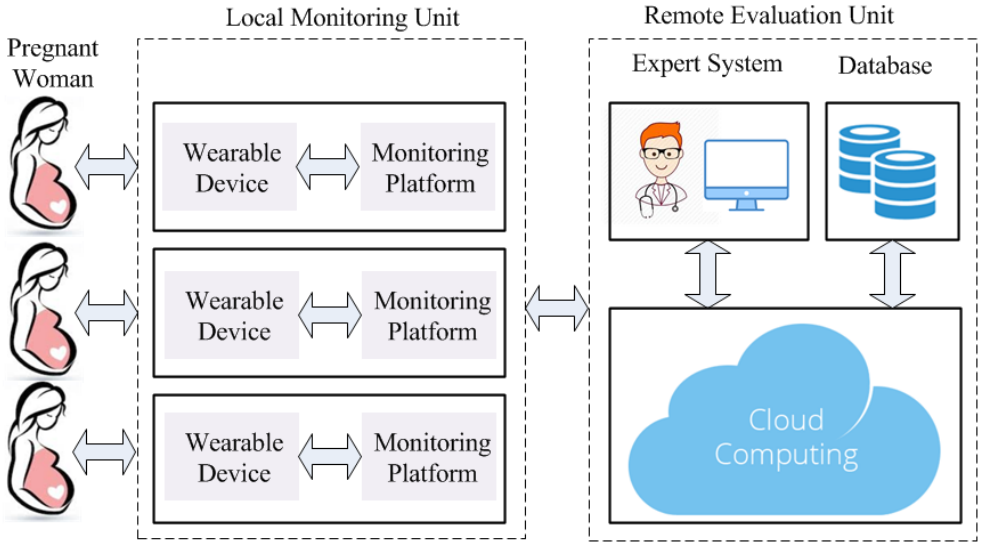
Components:

- Physiological sensors
- Connected garment
- Local diagnosis
- Cloud computing platform
- User interaction
- Global diagnosis
- Big data collection
- Self-learning

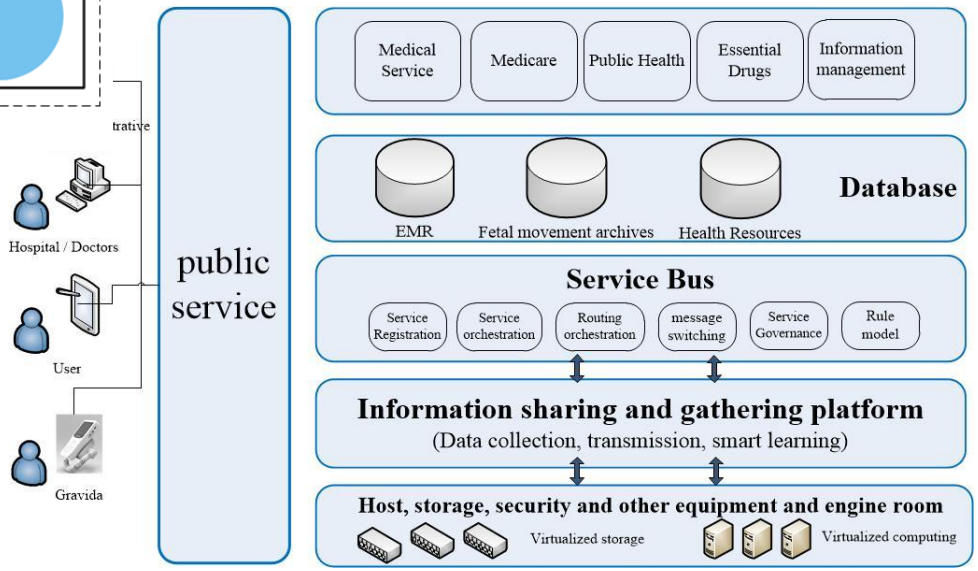
Intelligent wearable system: applications

Application 1: ANR – IOTFetMov

Intelligent garment for remote diagnosis of pregnant women



General structure



Architecture de la plateforme de cloud

Intelligent wearable system: applications

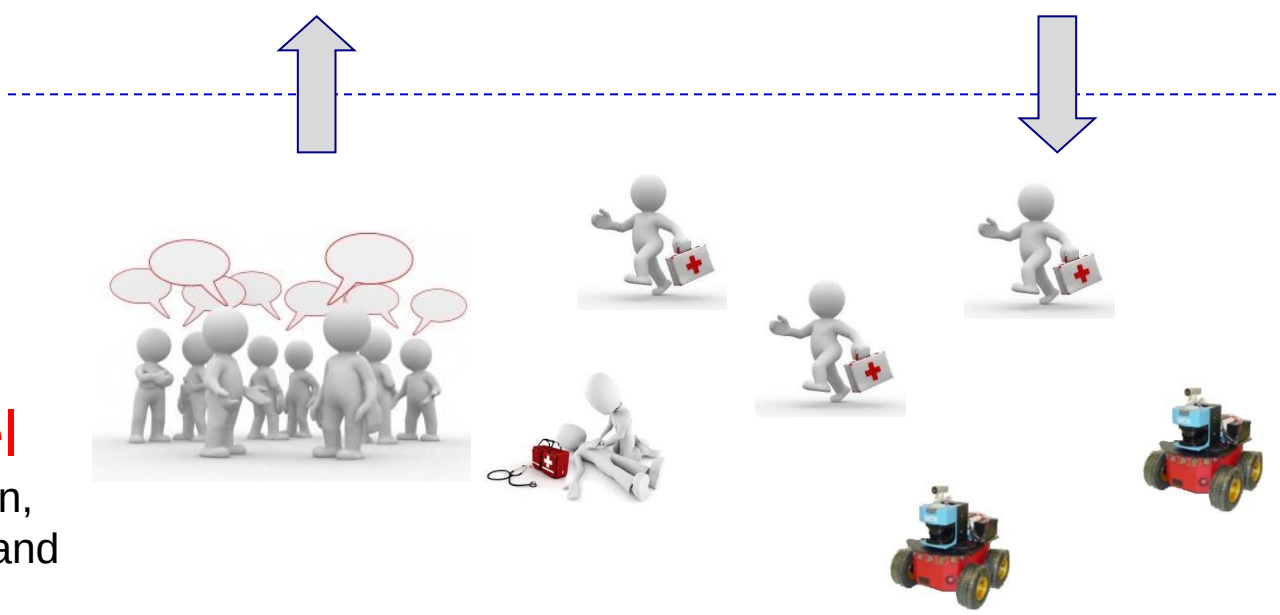
Application 2: ARCIR - SUCRé
Risk management by human-robot interaction

Strategic level
Global information and ressource management

Tactile level
Local information and ressource management

Operational level
Human-robot cooperation, monitoring of operators and environment

Crisis management unit

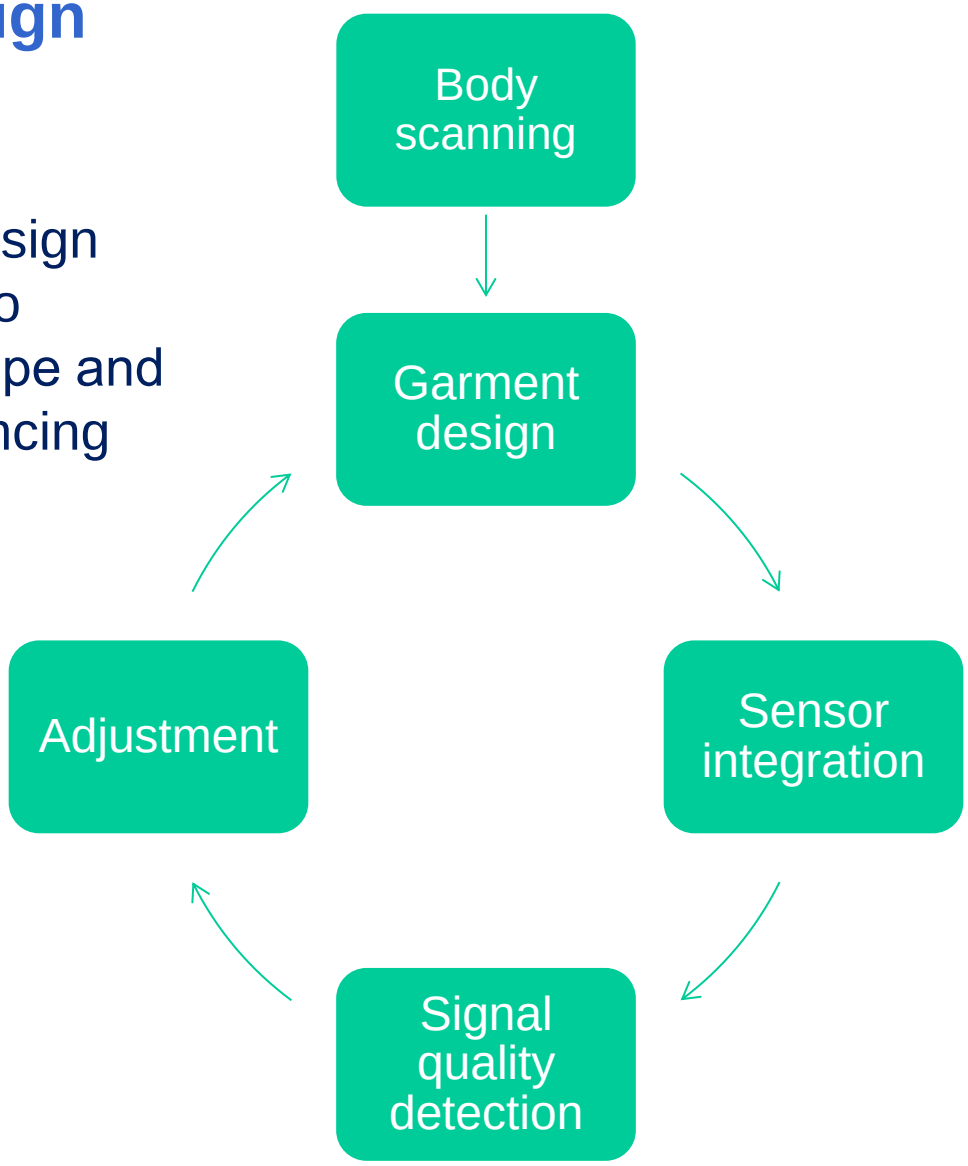


Real crisis scenario

Intelligent wearable system: applications

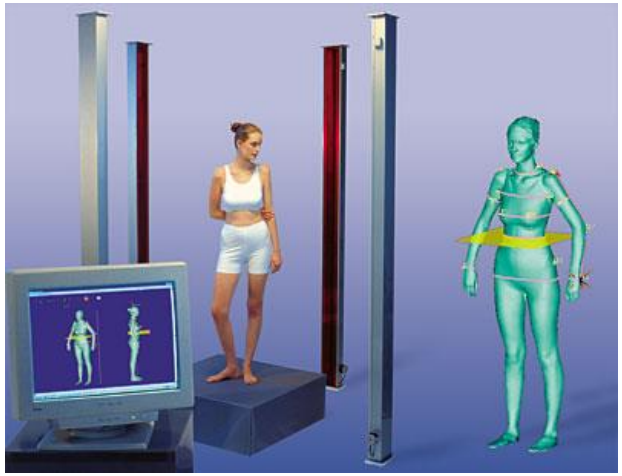
Proposed design process:

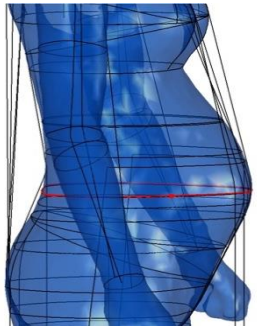
Creating a new design process adapted to wearer's body shape and comfort and enhancing the signal quality

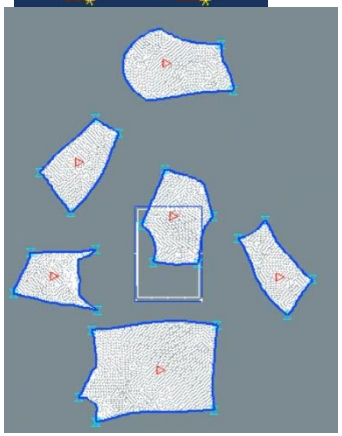


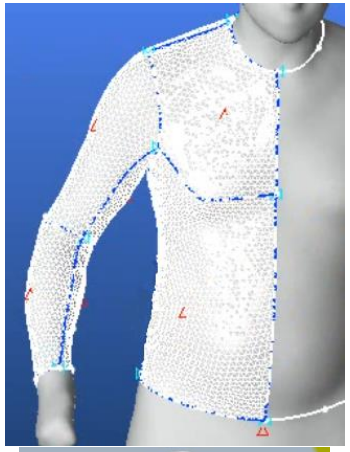
Intelligent wearable system: applications

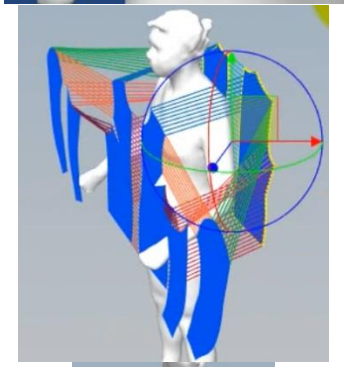
From human body data to garment pattern design







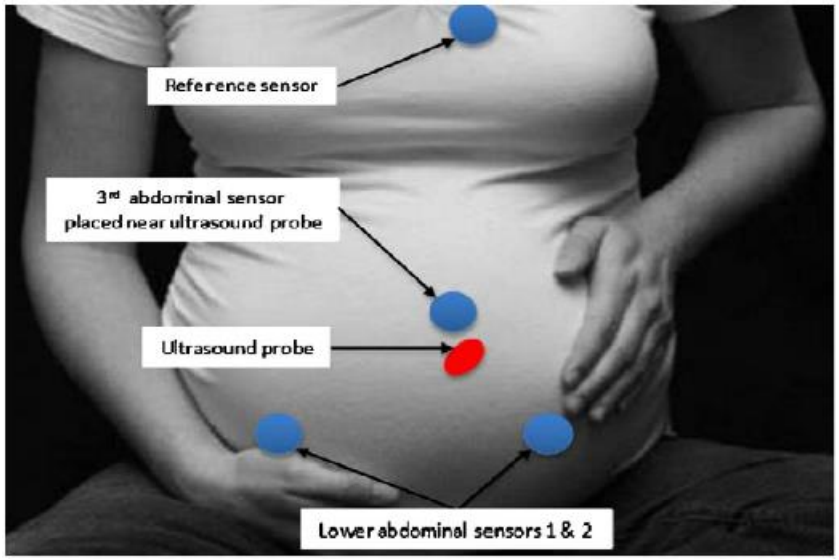


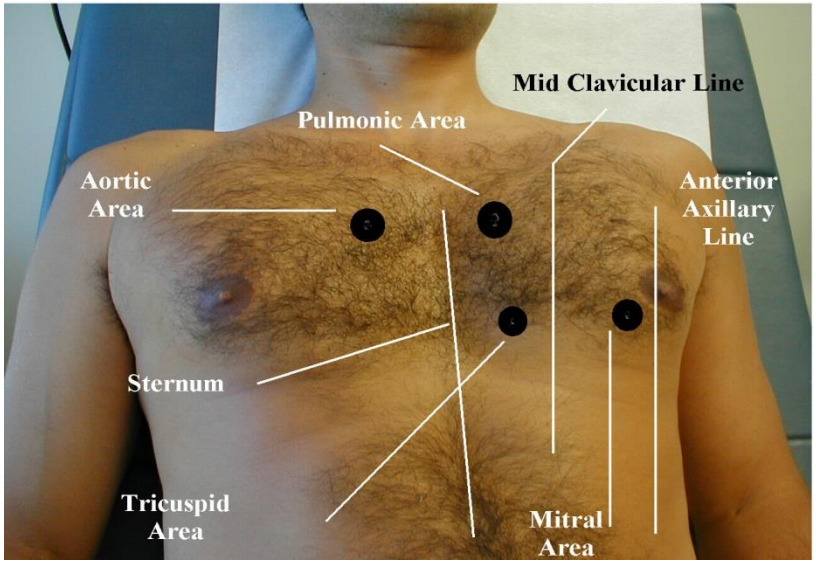


Intelligent wearable system: applications

Sensor integration
by considering measure
quality

Point of Maximum Impulse (PMI)



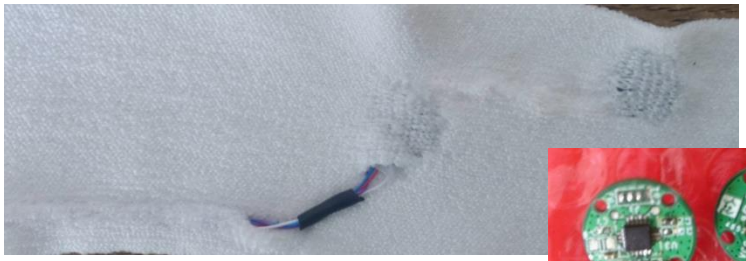


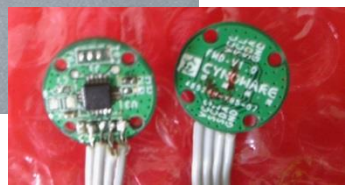
Intelligent wearable system: applications

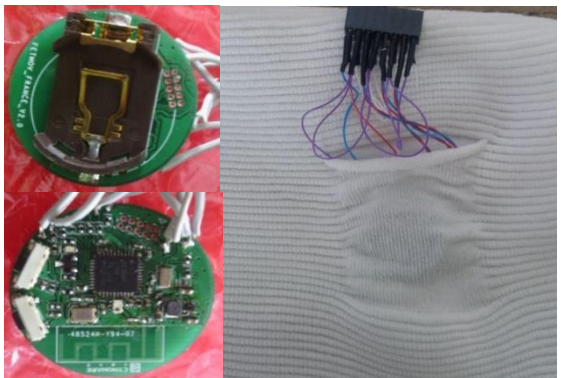
knitting

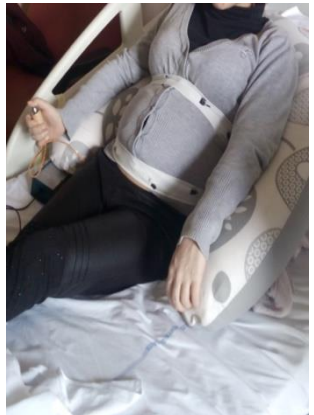
Sensor integration

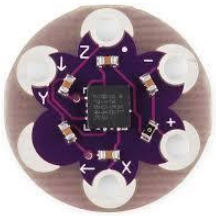
broidery

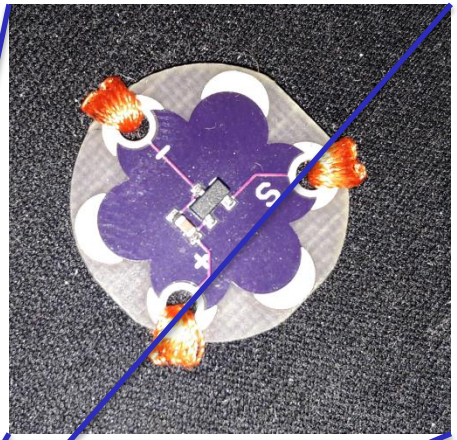


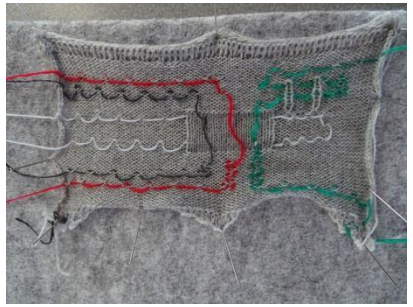












Intelligent wearable system: applications

The measuring system:

The parameters of the new sensor: 3rd version:

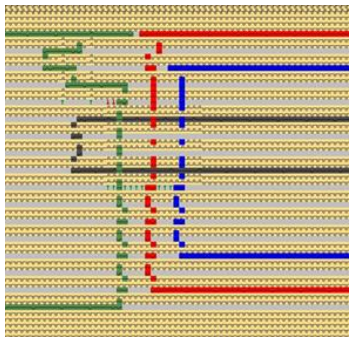
- ✓ A 8 bit microcontroller for communication with outside (Bluetooth, ZigBee)
- ✓ A 32 bit microcontroller for local decision support system and data processing
- ✓ A flash memory (256Mbits)
- ✓ The sensor: three axes for 14 bits at the frequency of 200 Hz
- ✓ Data transmission: 40Kbits/s

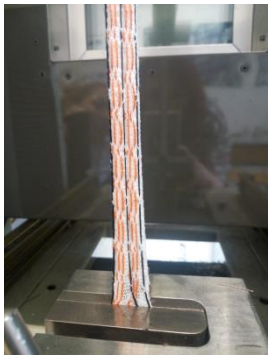
Intelligent wearable system: applications

Application 1:
Intelligent garment for remote diagnosis of pregnant women

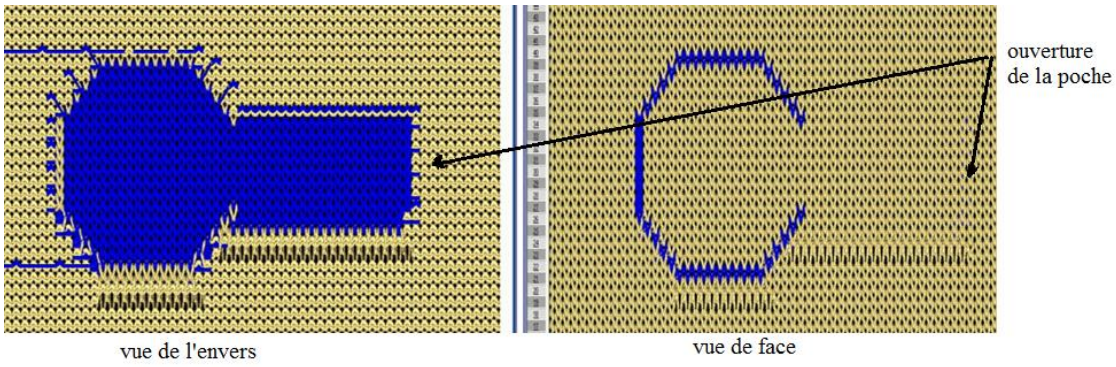
Textile and garment design:

- ✓ Principle : reliable data acquisition, comfort and washing stability
- ✓ Prototype : belt type
- ✓ Material: a mixture of polyamide (90%) and elasthan (10%)
- ✓ Conduction thread: datastretch Process: knitting
- ✓ Style : body scanner 3D => body shape evolution => adaptable belt





One sample with conduction thread



Intelligent wearable system: applications

Data communication

Choix de protocoles / choix de porteurs de courants faibles (énergie - signaux A/N)

ZigBee, Bluetooth, Wifi,…

☑ ZigBee protocol: an IEEE 802.15.4 standard

Modern network protocol employ a concept of layers to separate different components and functions into independant modules

- Message Routing to final destination
- Ad hoc network creation on the fly
- Self-healing mesh
- Minimum bytes to embedd payload

☑ BLE

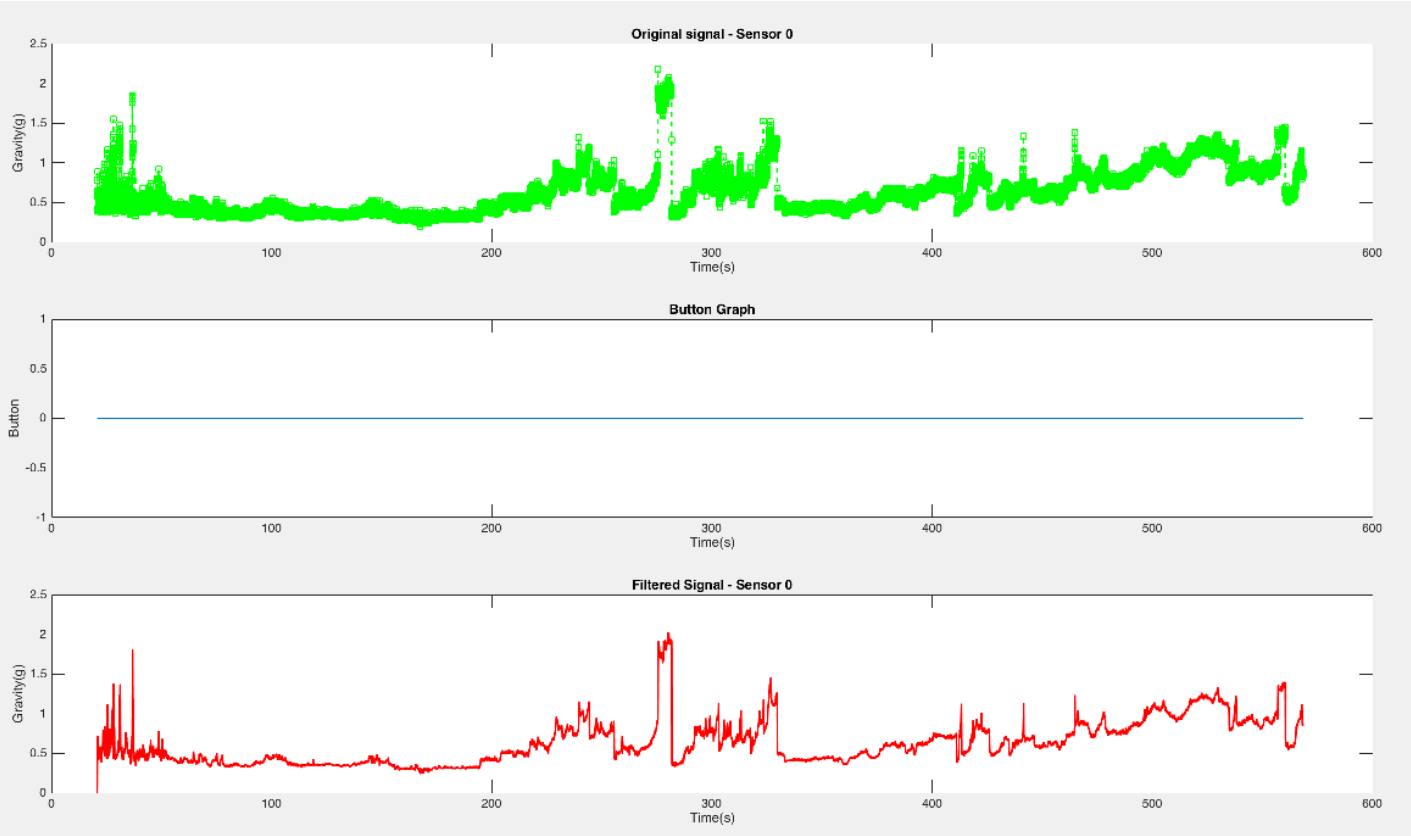
Modern network protocol

Mobile operating system compliance

Low power energy

Intelligent wearable system: applications

Application 1: identification of fetal movements

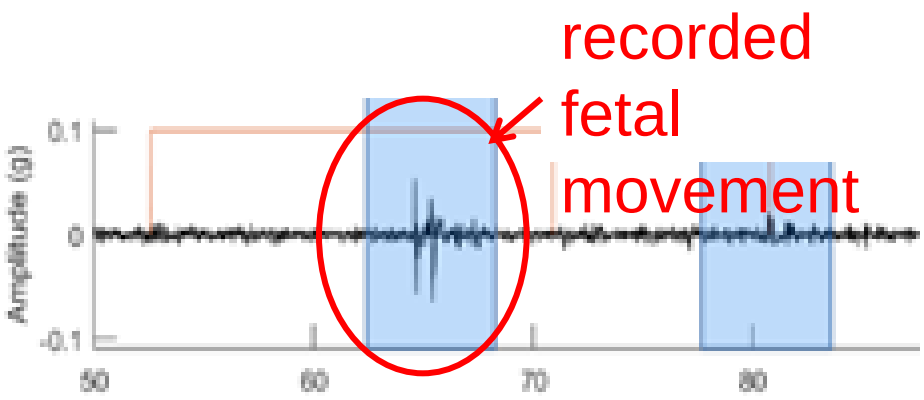


Original signal and signal filtered by wavelet analysis

Intelligent wearable system: applications

Application 1: identification of fetal movements

Workflow process



Data acquisition → Signal preprocessing → Signal classification → Fetal movement counting → Long-term monitoring

sensor | microcontroller | smartphone

Intelligent wearable system: applications

Application 1: identification of fetal movements

Android application user interface

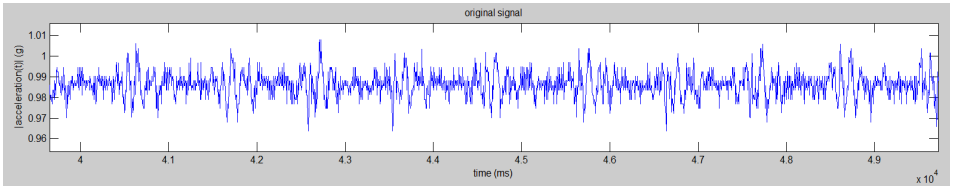
Total fetal movement counting since system startup

Instant view: Intensity for each fetal movement

Statistic view: fetal movement counting and corresponding intensity.

Intelligent wearable system: applications

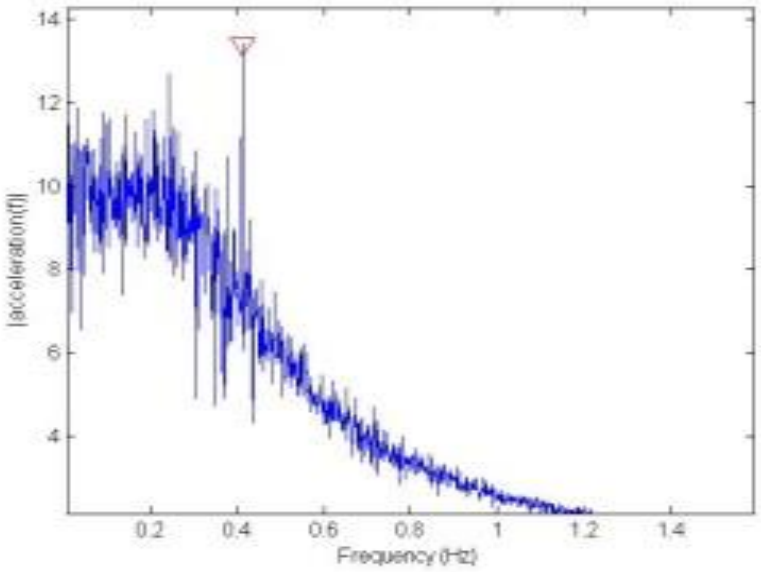
Application 2: identification of wearer's physiological signals



Raw signal

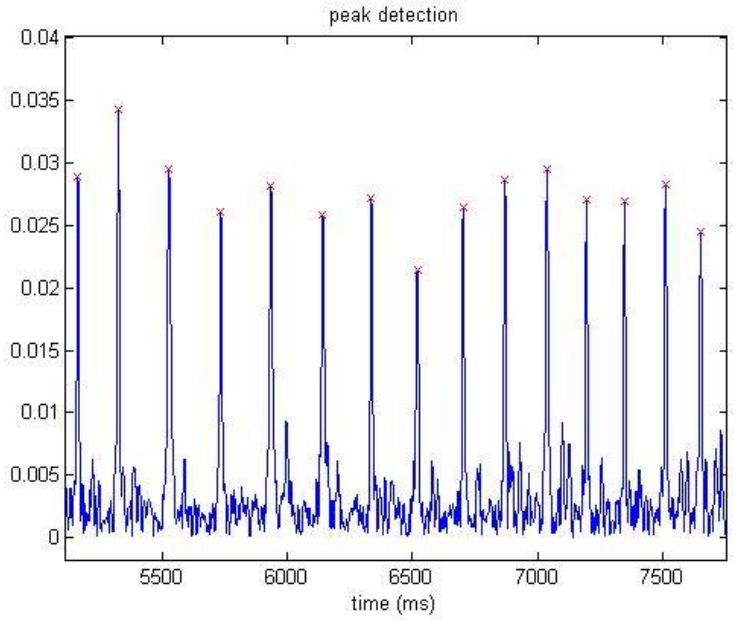
-Fourier
-Band filter (20/min)
-Peak detection

Respiration cycle



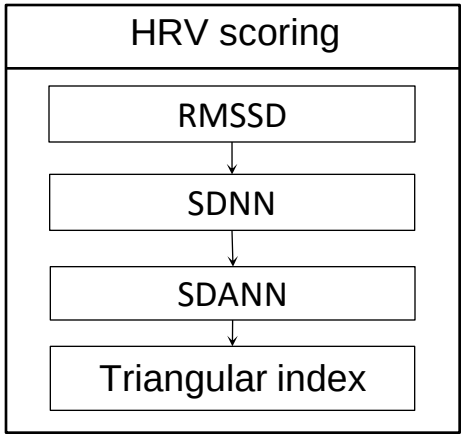
-Fourier
-Band filters

Heart Beat



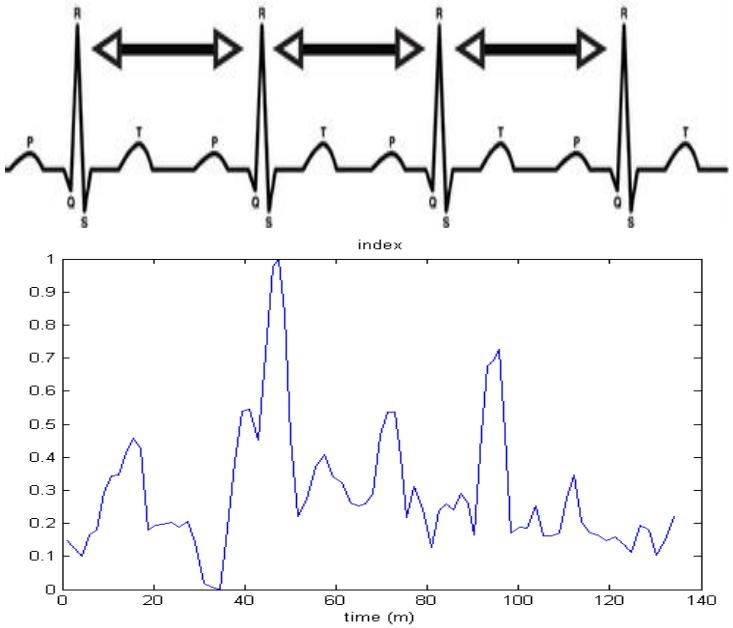
Intelligent wearable system: applications

Application 2: identification of wearer's physiological signals



SDNN (estimate of overall HRV): reflecting all the cyclic components responsible for variability during the recording

SDANN (estimate of short-term components of HRV): the changes in heart rate due to cycles longer than 5 minutes

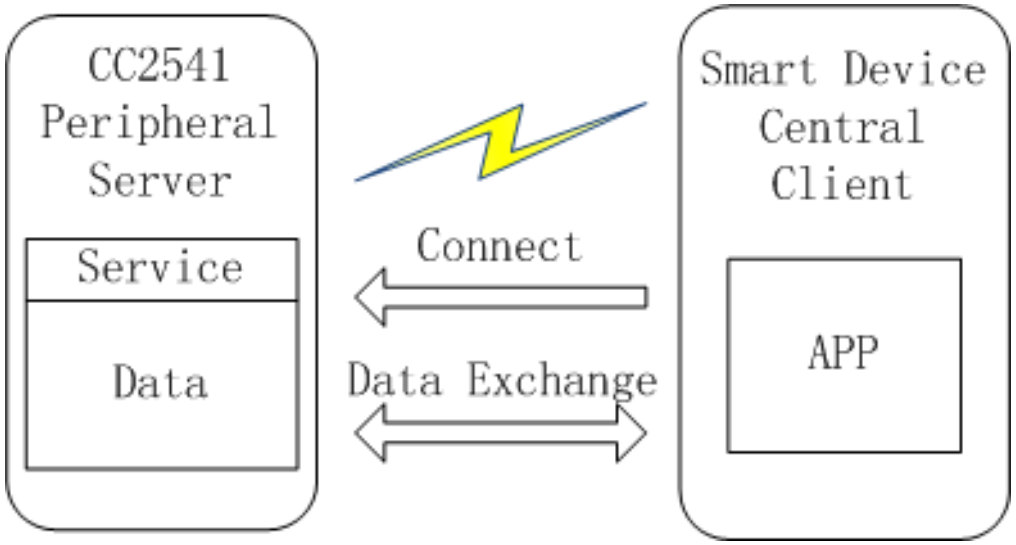


HRV triangular index (estimate of overall HRV): the integral of the density distribution divided by the maximum of the density distribution

Intelligent wearable system: applications

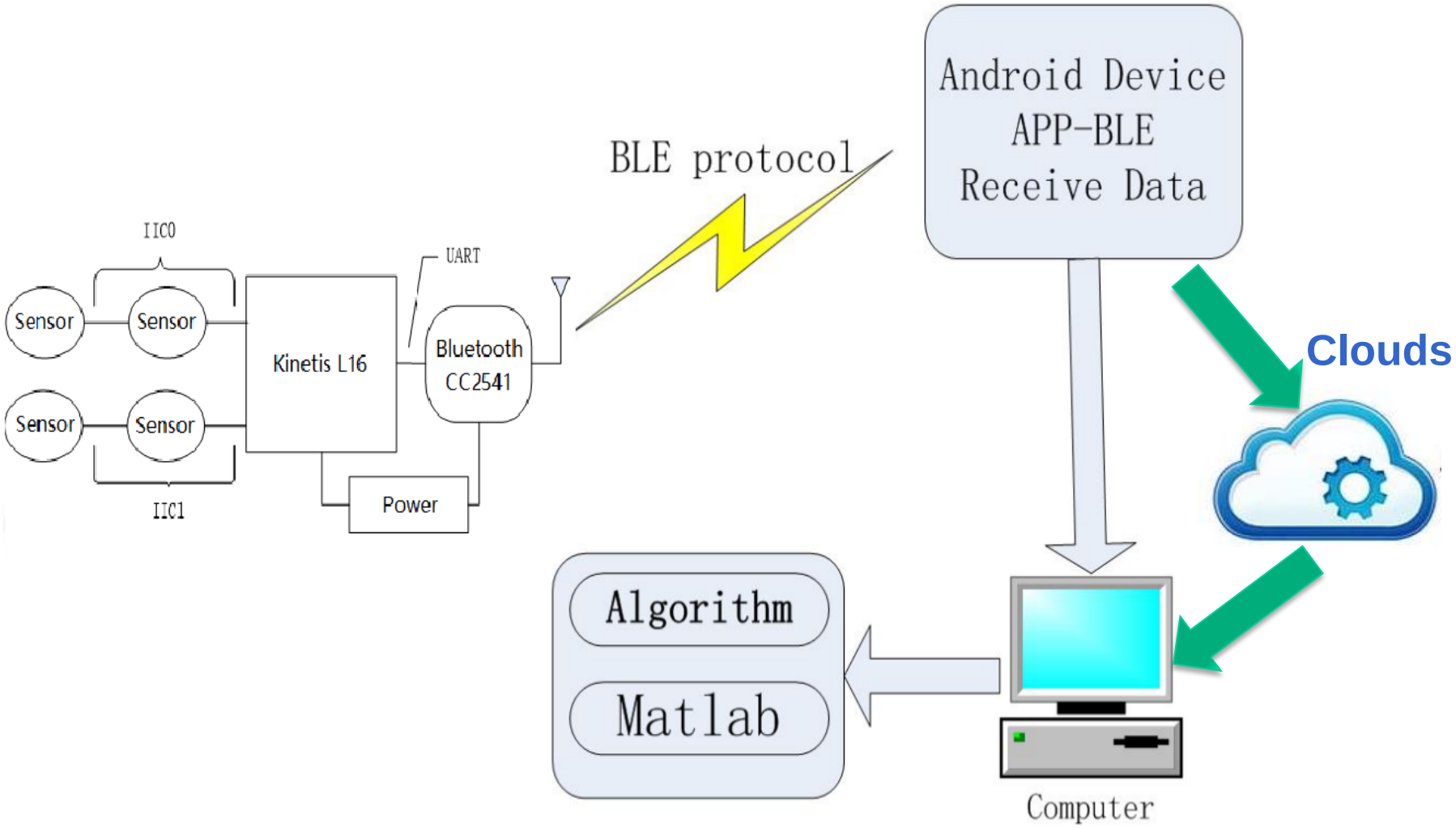
Communications:

- BLE(Bluetooth Low Energy) Protocol Stack 4.0
  - Aimed at novel healthcare, fitness, security and home entertainment industries
  - Provides reliable connections and reduce power consumption and cost while maintaining a similar communication range
  - Communication
  - Model



Intelligent wearable system: applications

Communications:



Perspectives

- Integrating multiple (electronic and textile) sensors and multiple flexible and rigid materials (textile, 3D printing and others) to form an complete wearable system
- Enhancing the autonomy and intelligence level of the microcontroller/embedded system
- Developing a systematic design approach by combining signal quality, comfort and aesthetic level
- Integrating more complex scenarios on emotional and physiological analysis
- Developing interactions between the garment, android devices and cloud computing platform
- Wearable system: ICPS (Industrial Cyber-Physical System) requiring multidisciplinary efforts (sensor, actuator, design, material, signal processing, decision support, physiology, psychology)