Interactions Humain/Textile/Environnement à l'Ere Digitale

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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):**

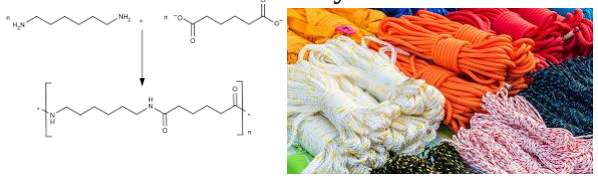
  France Télécom, Orange, CHRU, Unilever, Decathlon, Damart, Adidas, Chanel, …
- **European and national projects:**

  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:

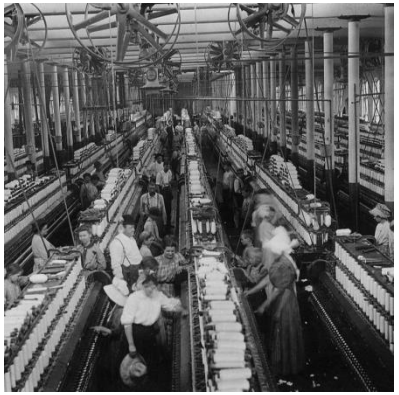
End of the 19th century: first **chemical** fiber



1784: first mechanical loom

Steam-powered **mechanical** manufacturing

End of the 19th century: first textile production

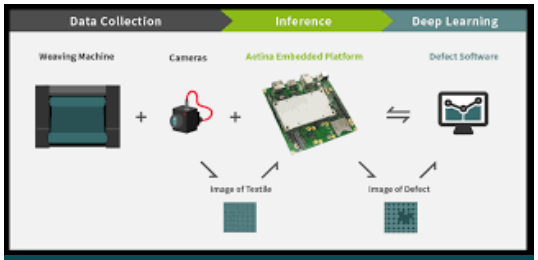


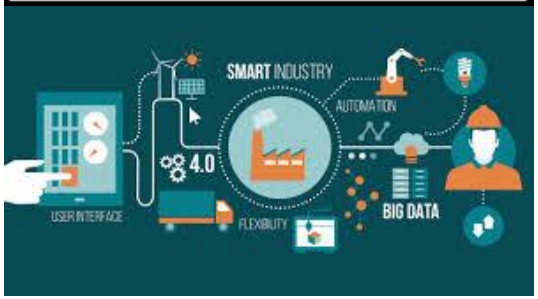
Electricity-powered mass production

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.)

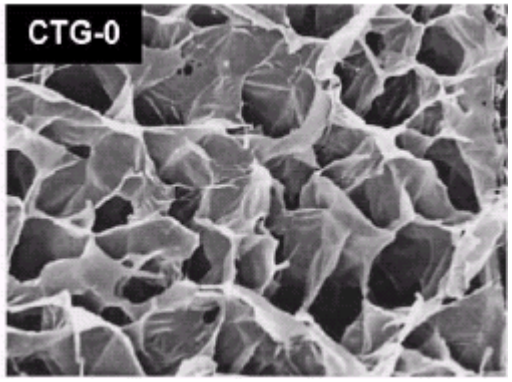
Response (change..) R => actuators

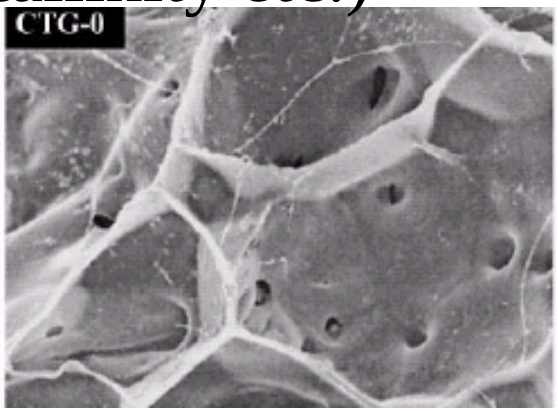
Shape (swelling, shrinking)

Colour (shade, intensity)

Electrical conductivity

State of matter (phase change, crystallinity etc.)





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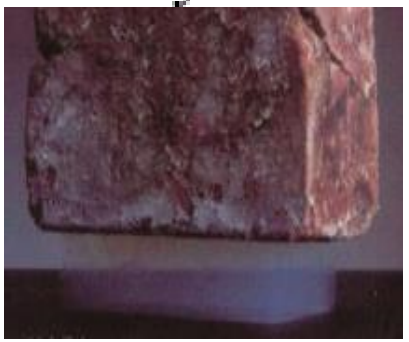
Smart structures

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

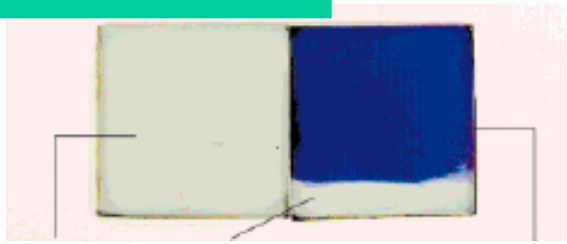


- Synthesize new materials and structures by compositing known constituents
  - Active elements attached to the structure (parasitic)
  - Active elements embedded in the structure

Smart Materials

Active and passive smart textiles: reversible

electrochromic

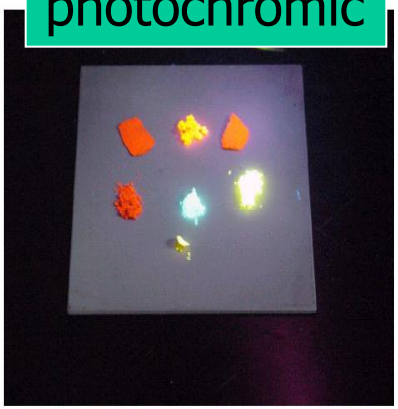


oxidation reduction

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

diabetes

photochromic

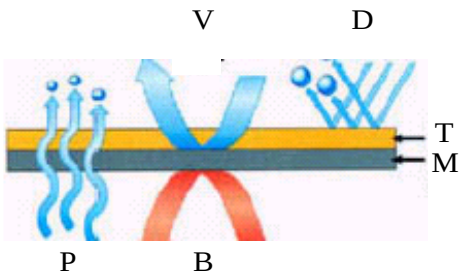


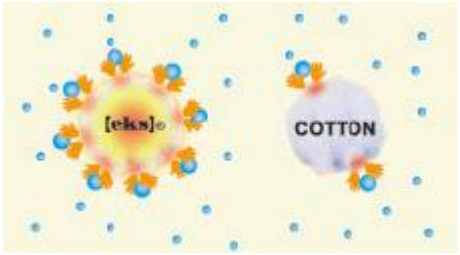
Active smart textiles

- Shape memory

(reversible form changes due to heating and cooling)

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

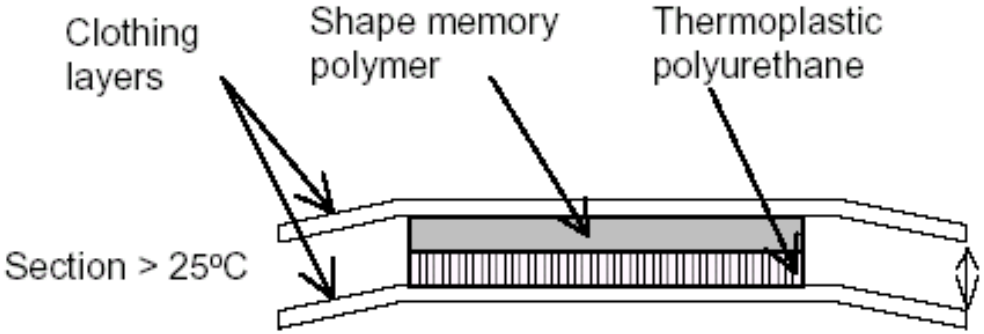


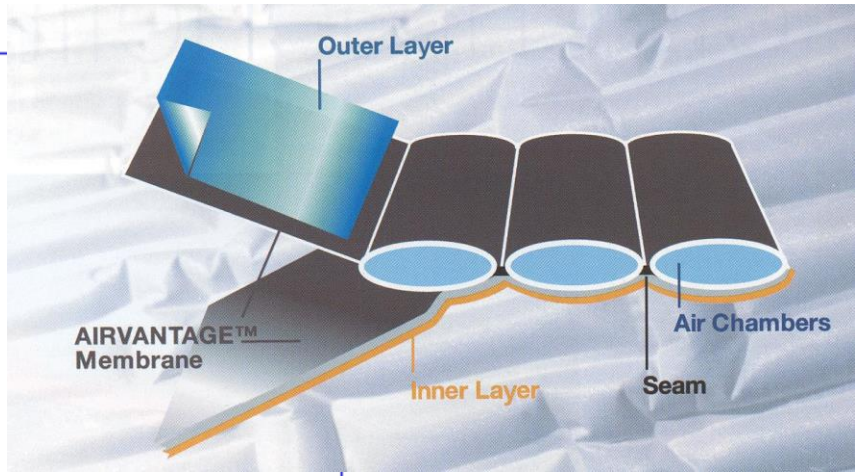


Smart Materials

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)

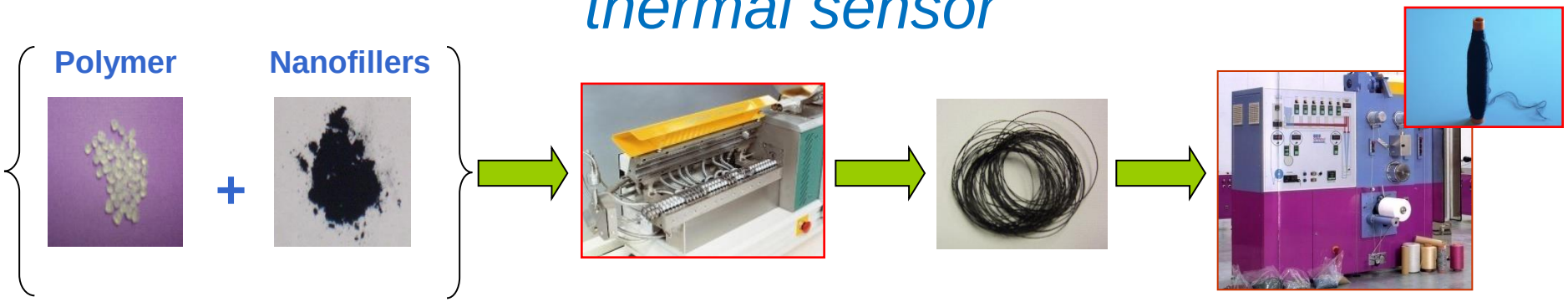
Textile materials for sensing and actuation:

- 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

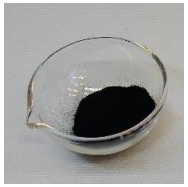
Thermal sensors

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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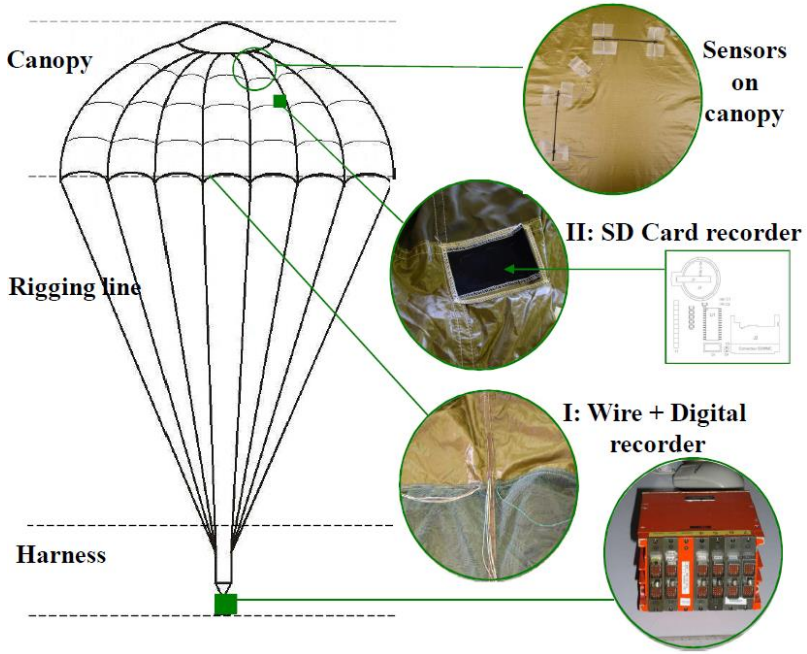
Thermoplastic elastomer

Conductive polymer composite by solvent process

Sensor on polyamide 66 fabric

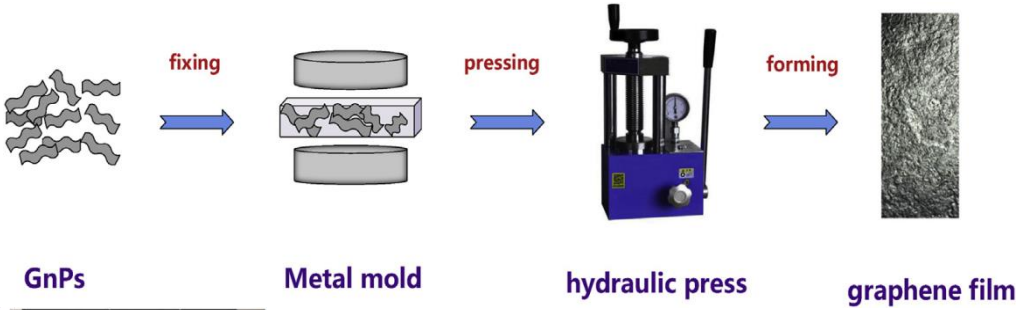


Elaboration by **solvent deposition** of conductive track whose electrical conductivity varies with external stress.

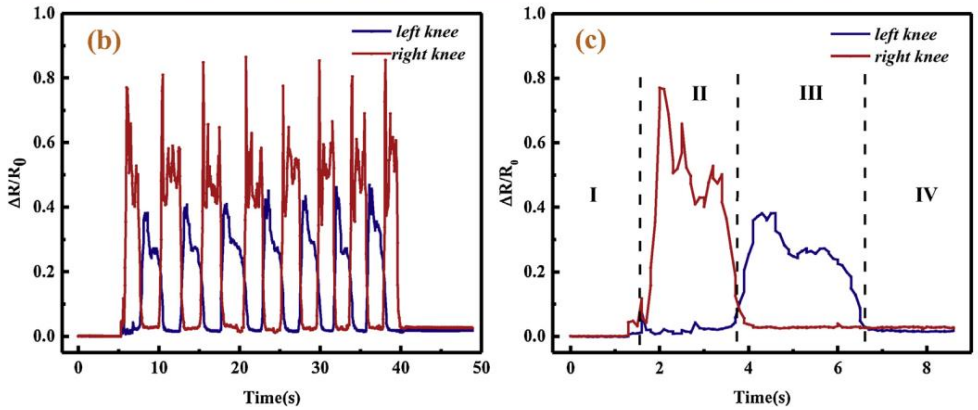
Textile Sensors and actuators

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

Graphene: crystalized bi-dimensional material



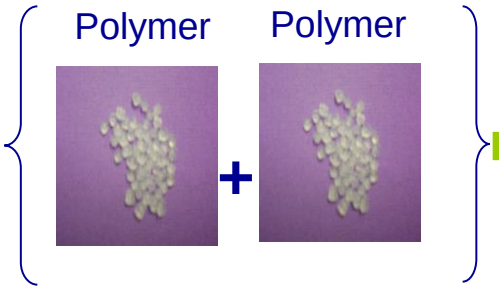
A flexible and high conductivity graphene film is fabricated by thermal expansion-pressing forming process



Human motion monitoring

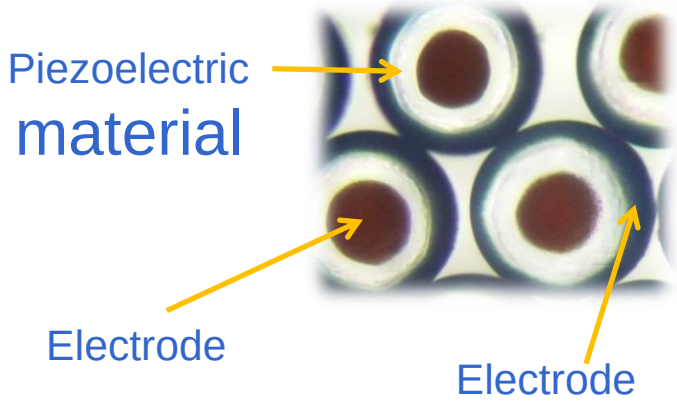
Smart Materials: Textile Sensors and actuators

Formulation of mixed immiscible polymers for defined morphologies

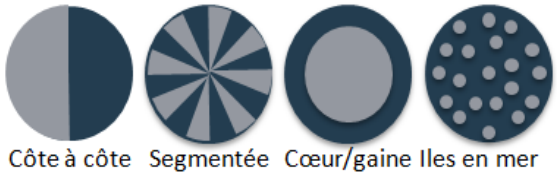


CETI

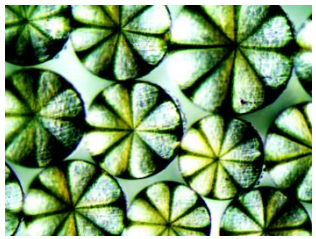
Development of tricomponent piezoelectric polymer fibers for energy harvesting textiles

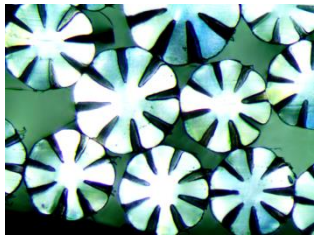


Tricomponent Melt



Nanofibres





Ultra fine fibre for air filtration

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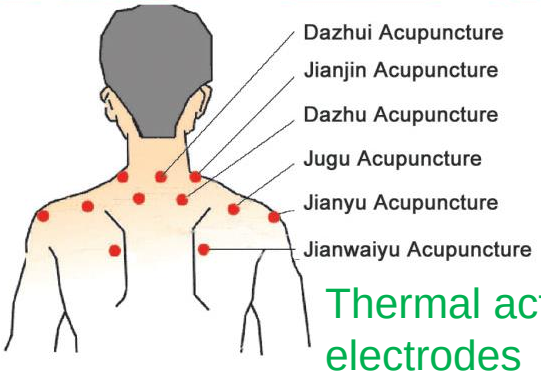
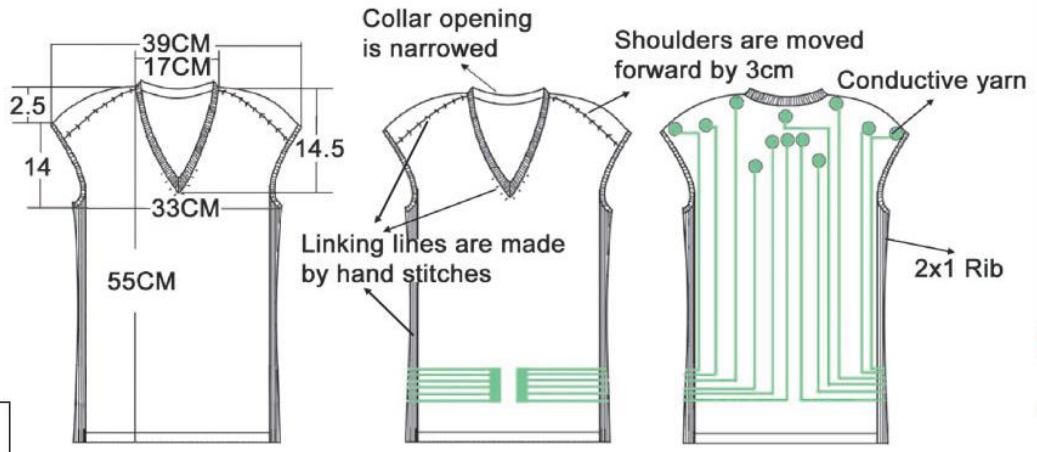
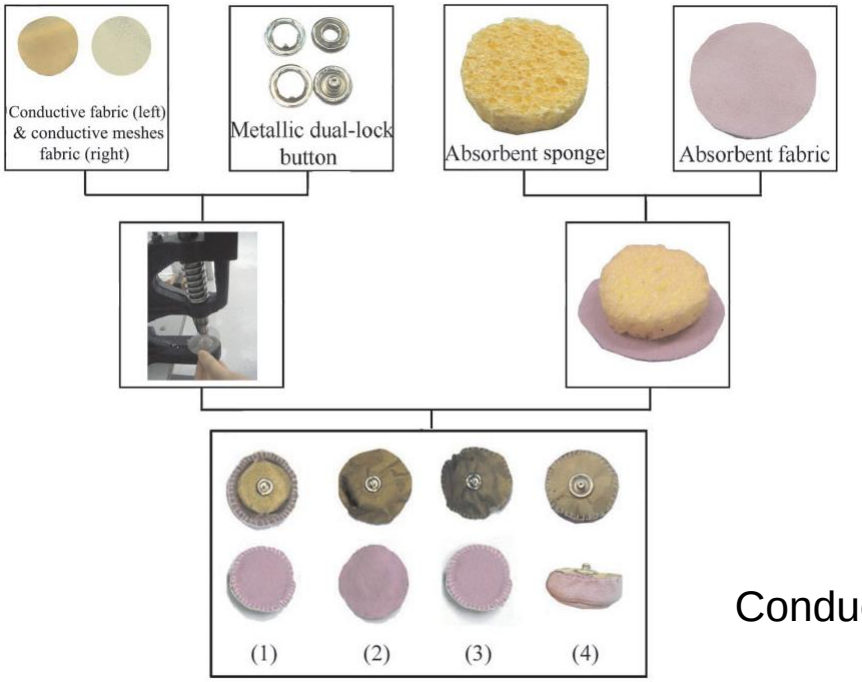
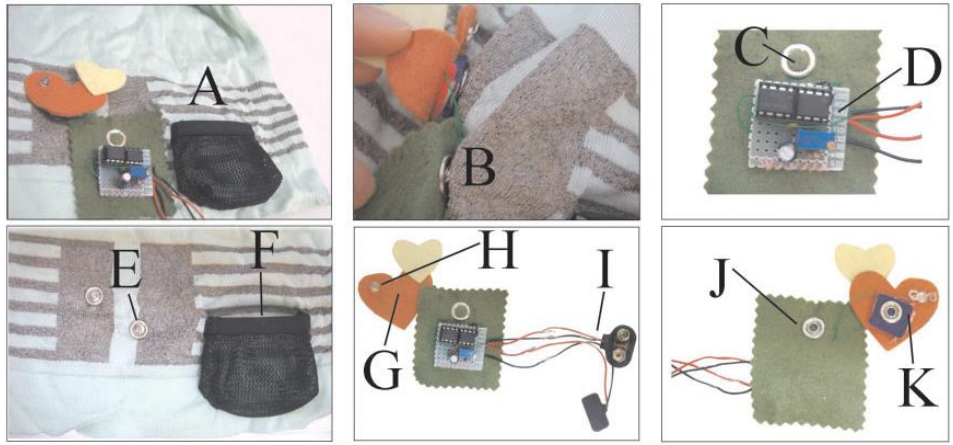
Fabric thermal actuation: transcutaneous electrical nerve stimulation => knitwear design



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

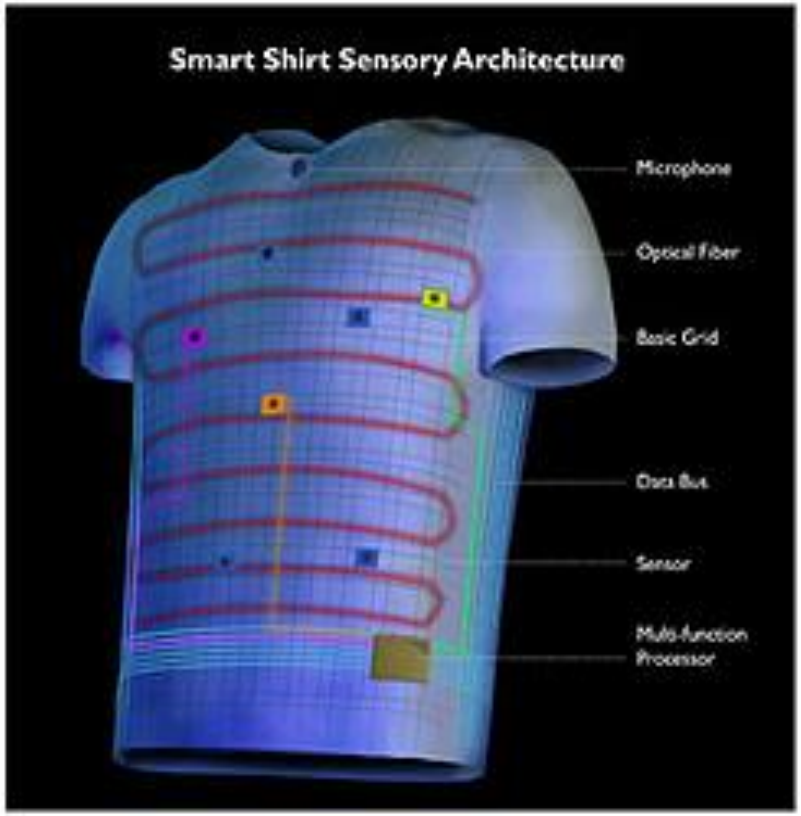
Music jacket

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

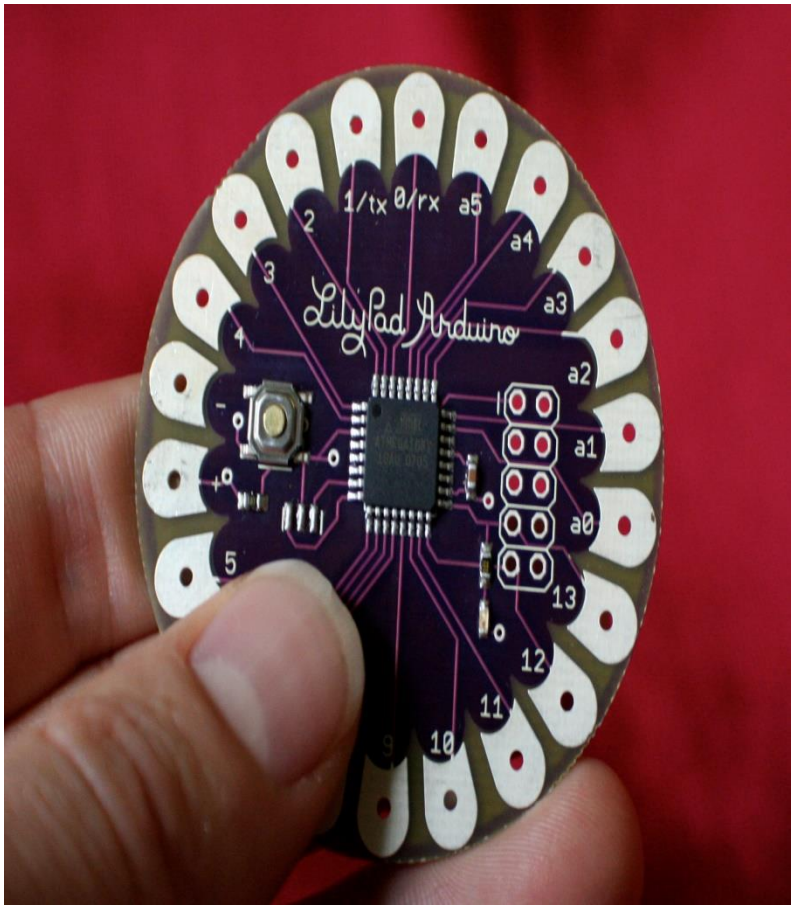
- Fashion design
- Medical diagnosis
- Security, protection and risk management
- Sport
- Human cooperation

2007 - One hundred eleven

Wearable system: basic components – micro controller

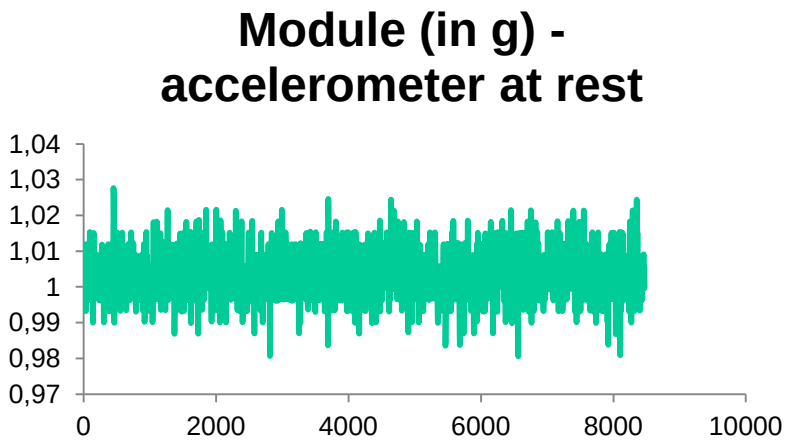
LilyPad Arduino

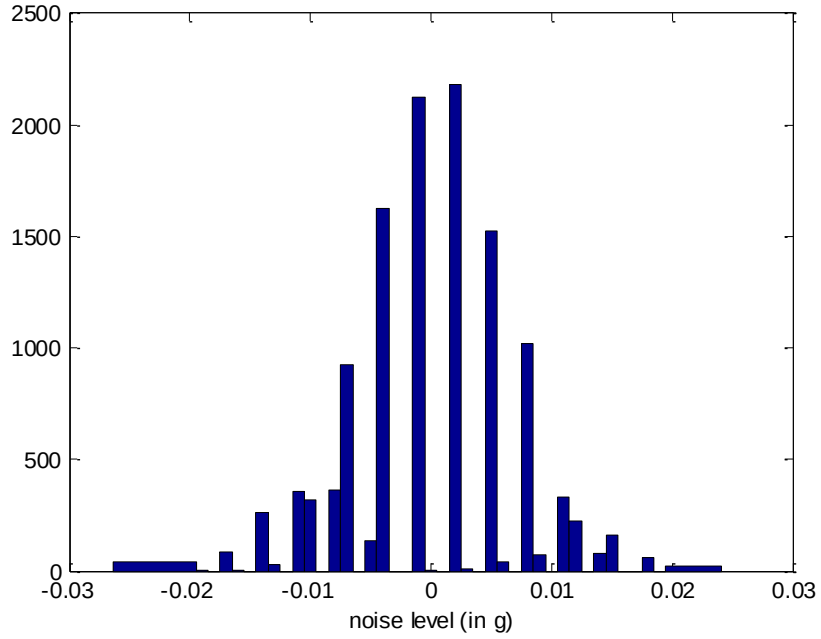
- A microcontroller board for e-textiles, sewed to fabrics and mounted power suppliers, sensors and actuators
- Programming with the Arduino software
- Small size: a circle of 50mm in diameter
- Washable



Intelligent clothing: electronic and textile integration process

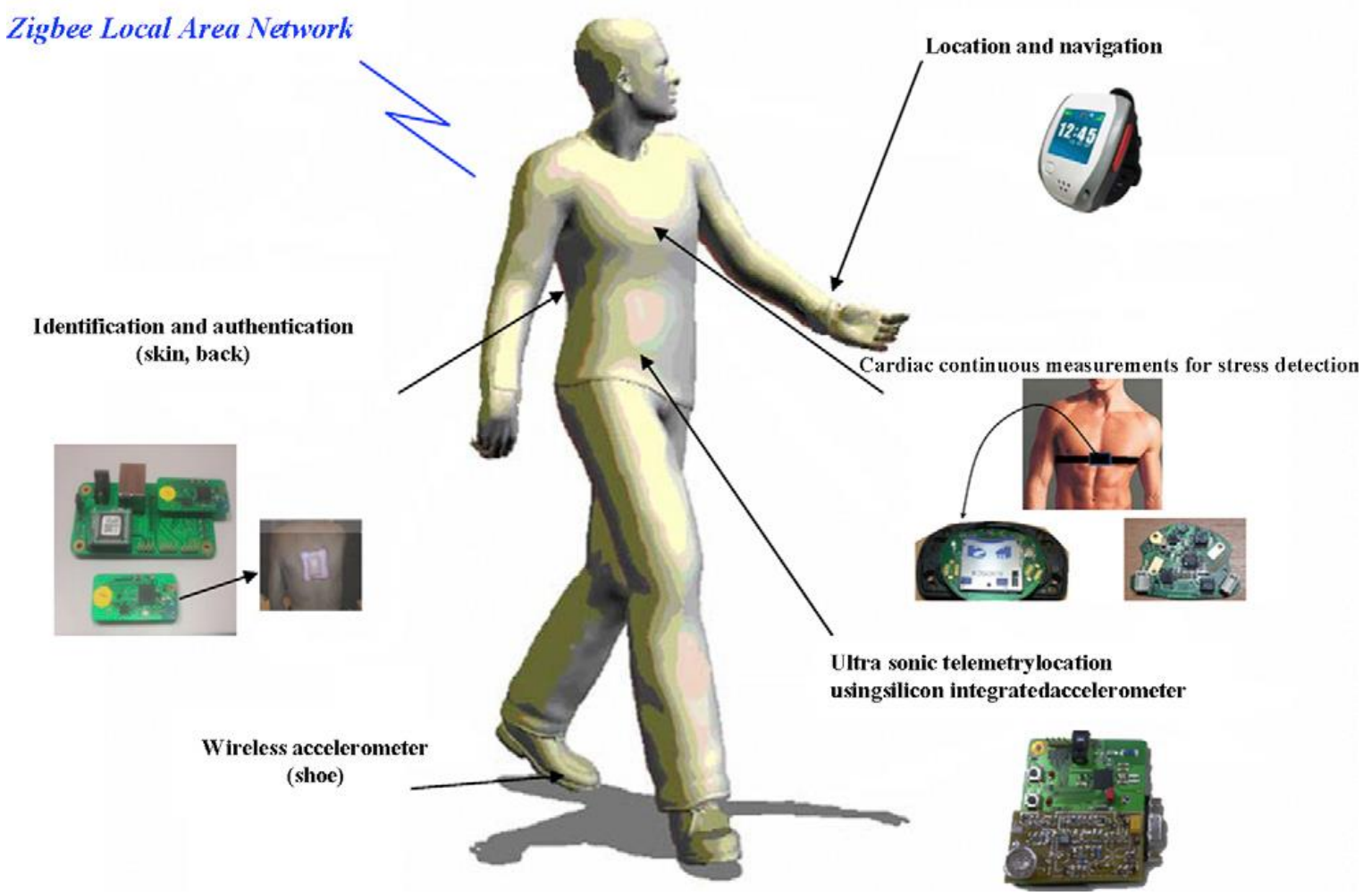
Wearable system: basic components – sensors





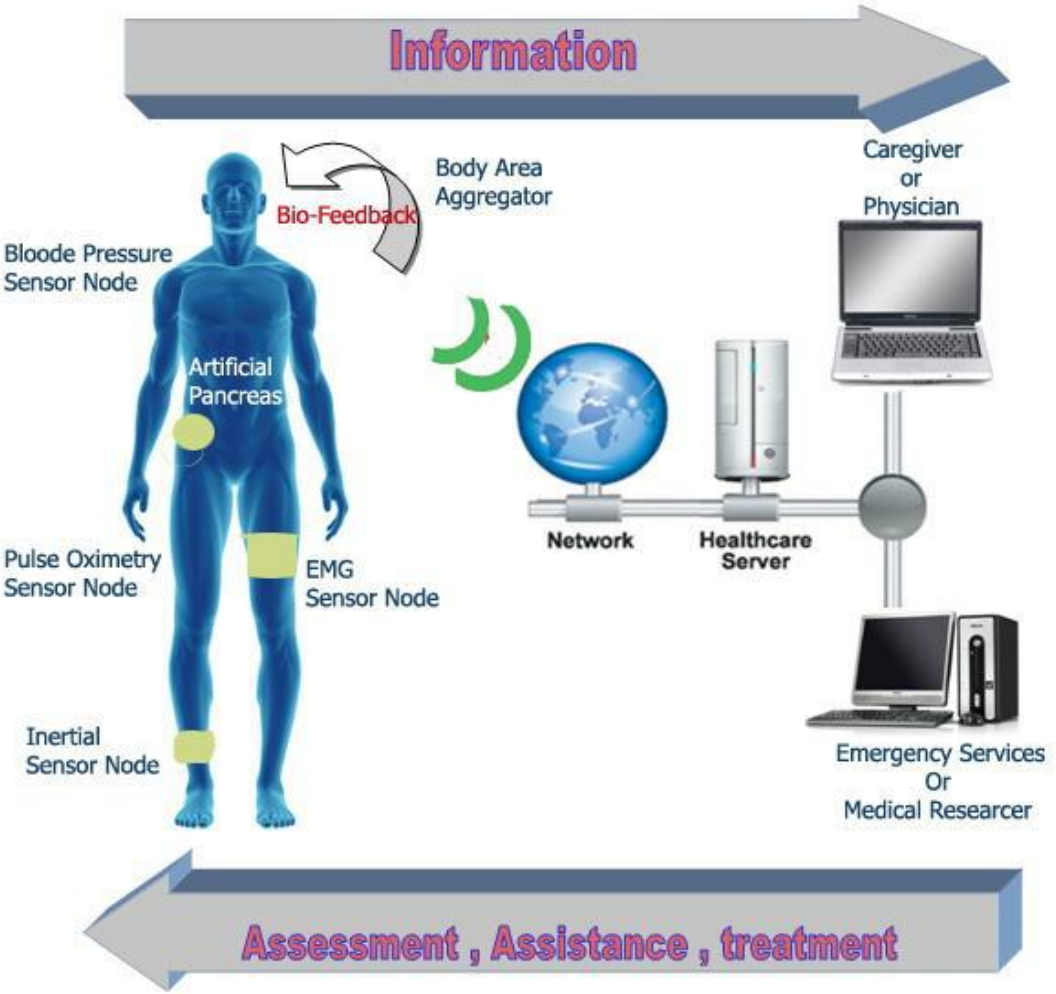
Intelligent clothing: electronic and textile integration process

Intelligent garment for monitoring health state



Intelligent clothing: electronic and textile integration process

Intelligent garment for remote diagnosis



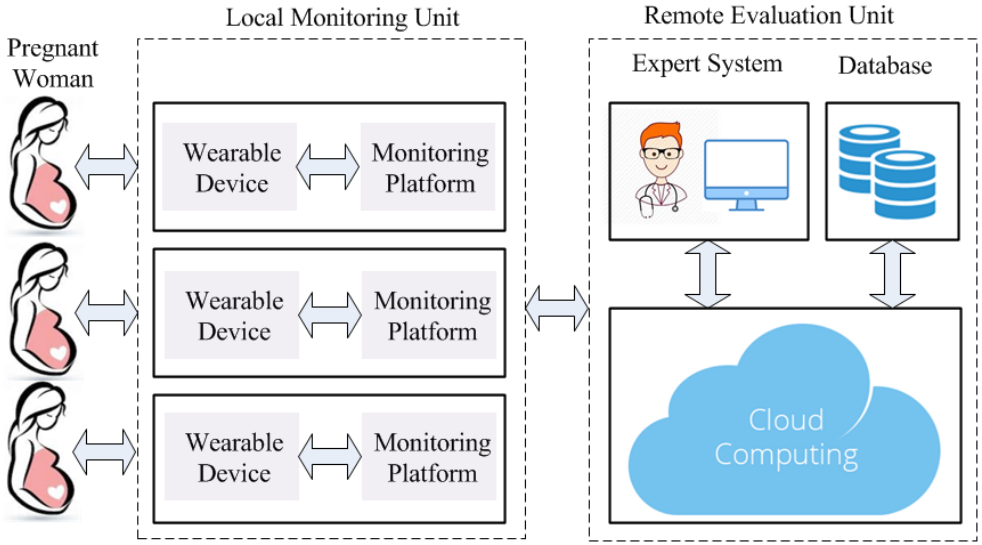
Components:

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

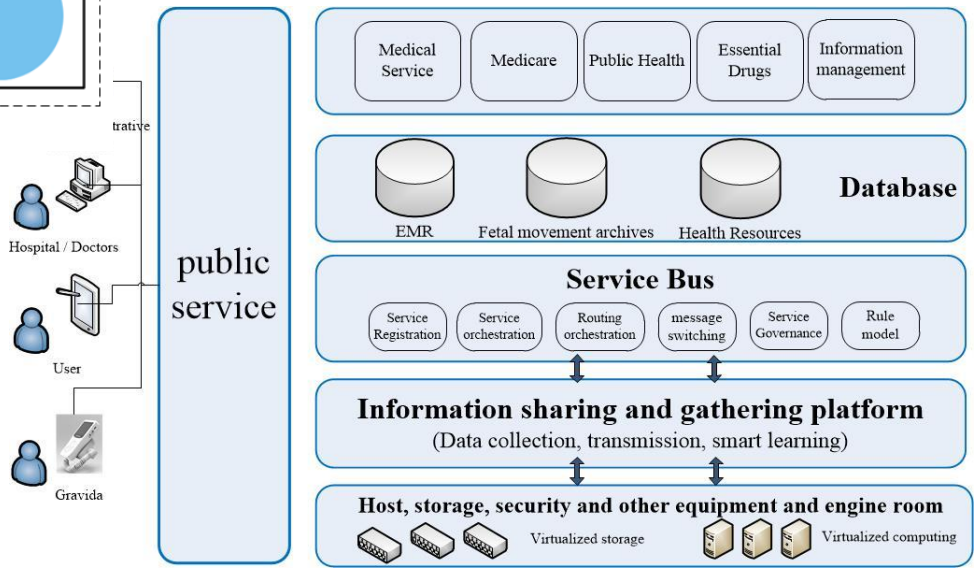
Intelligent wearable system: applications

Application 1: ANR – IOTFetMov

Intelligent garment for remote diagnosis of pregnant women



General structure



Architecture de la plateforme de cloud

Intelligent wearable system: applications

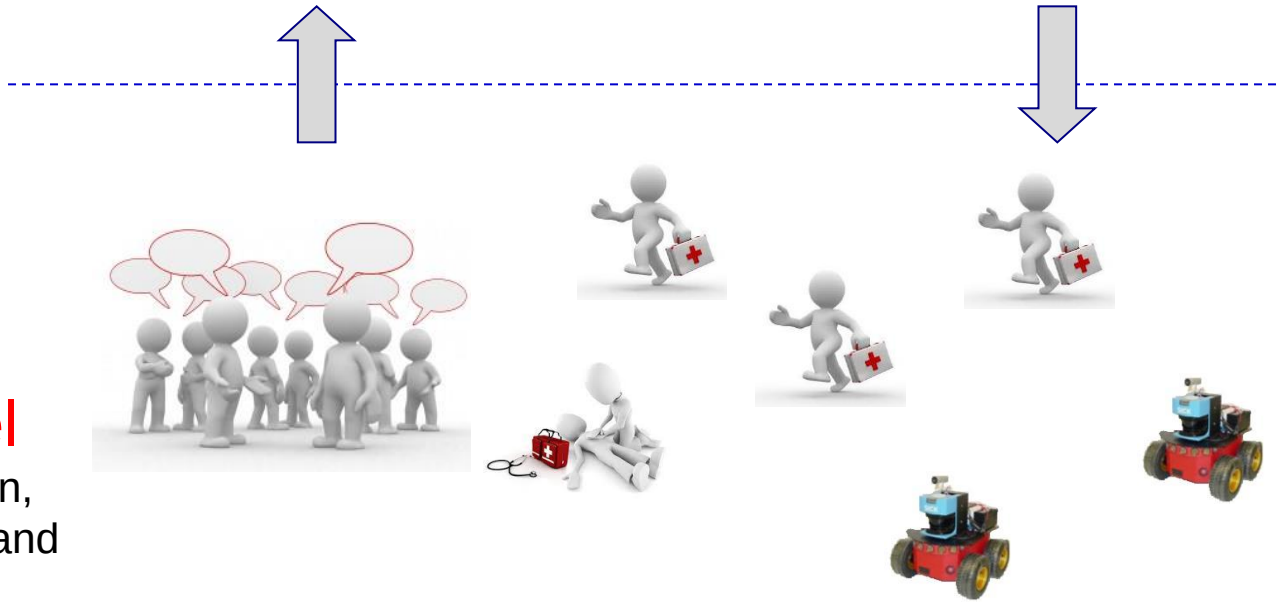
Application 2: ARCIR - SUCRé
Risk management by human-robot interaction

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

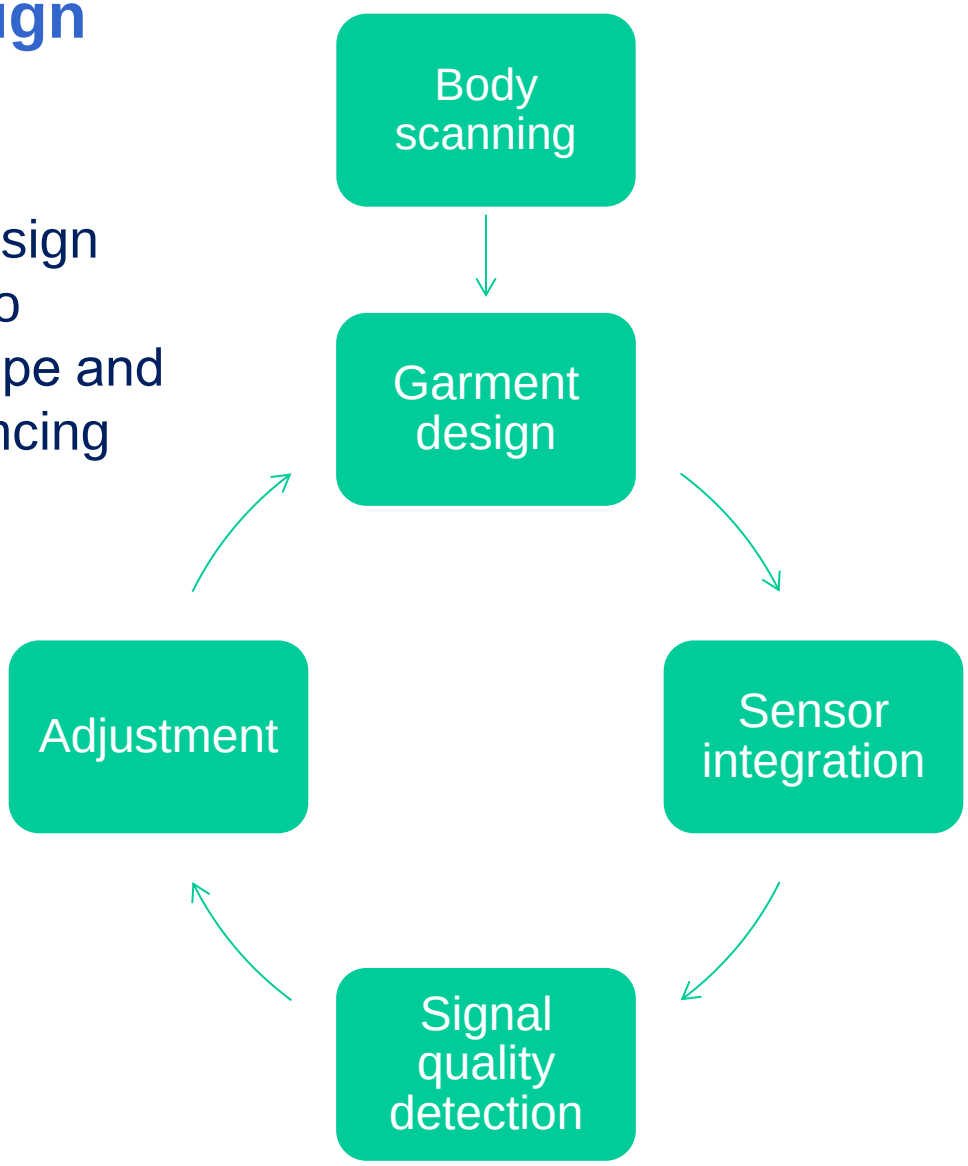


Real crisis scenario

Intelligent wearable system: applications

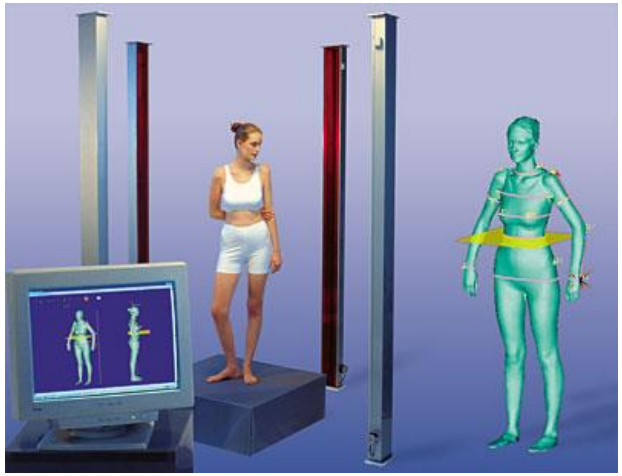
Proposed design process:

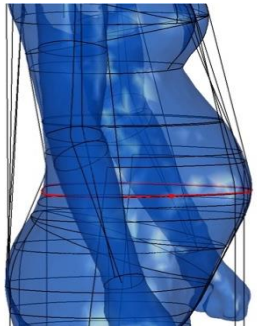
Creating a new design process adapted to wearer's body shape and comfort and enhancing the signal quality

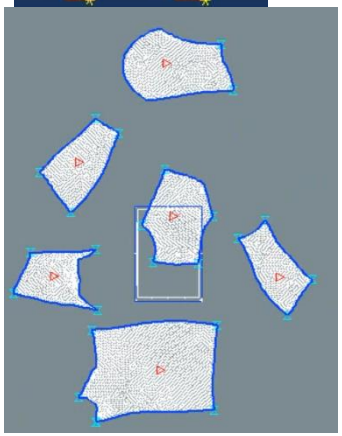


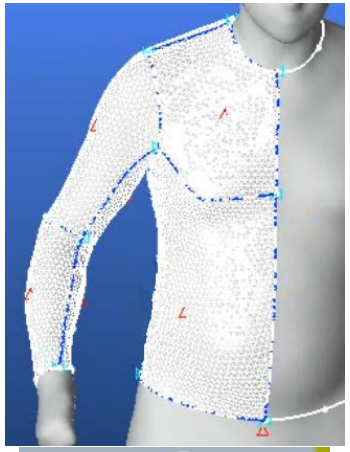
Intelligent wearable system: applications

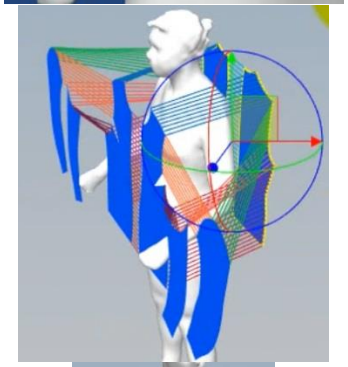
From human body data to garment pattern design







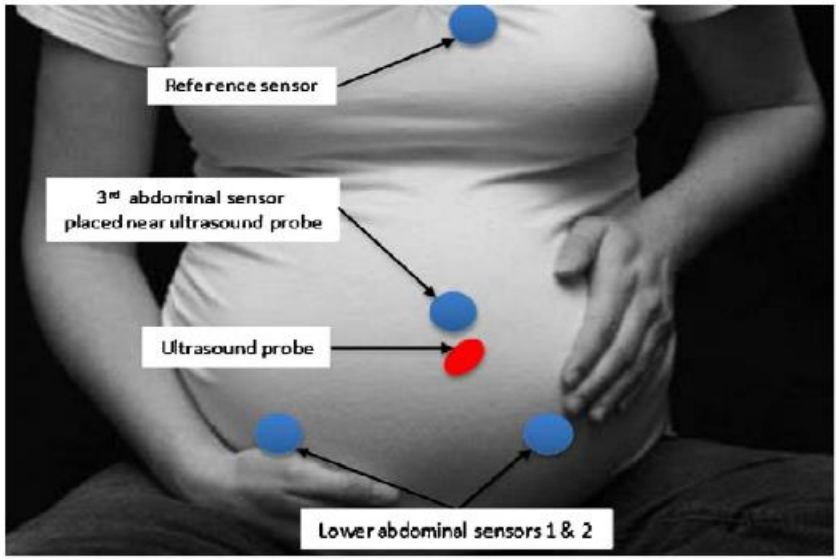


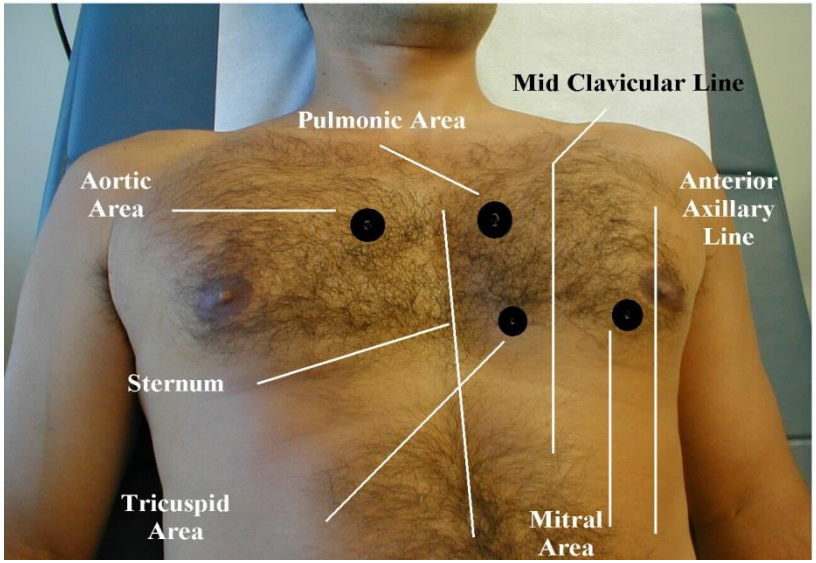


Intelligent wearable system: applications

Sensor integration
by considering measure
quality

Point of Maximum Impulse (PMI)



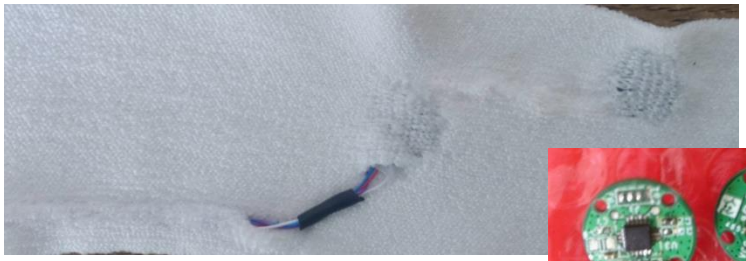


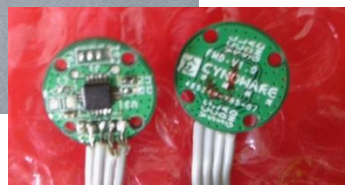
Intelligent wearable system: applications

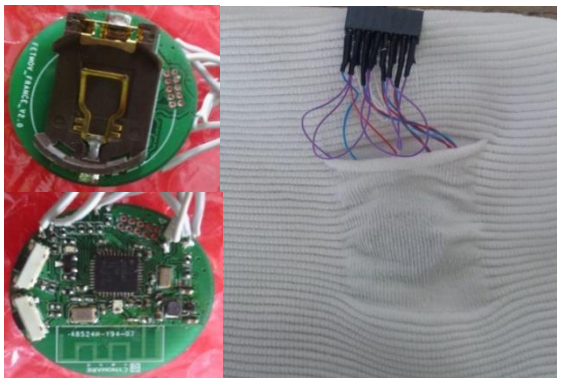
knitting

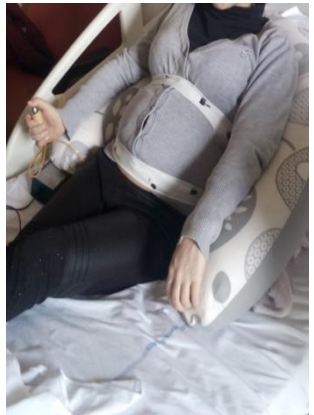
Sensor integration

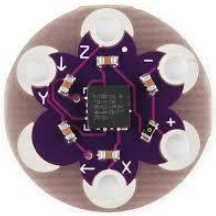
broidery

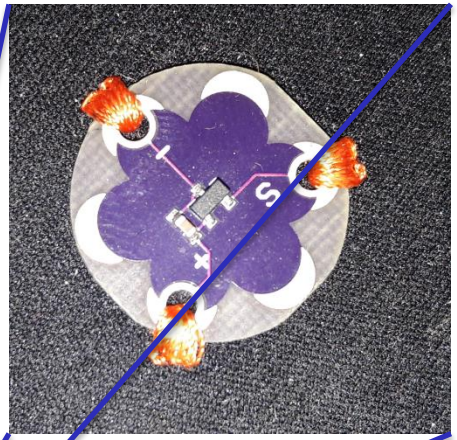


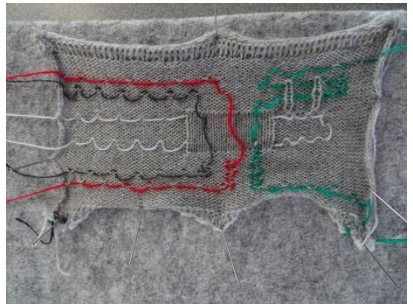












Intelligent wearable system: applications

The measuring system:

The parameters of the new sensor: 3rd version:

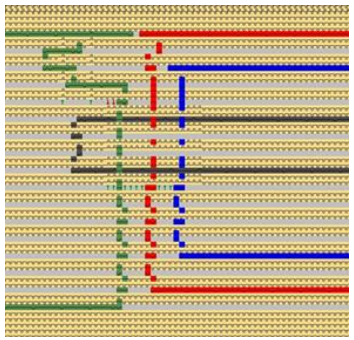
- ✓ A 8 bit microcontroller for communication with outside (Bluetooth, ZigBee)
- ✓ A 32 bit microcontroller for local decision support system and data processing
- ✓ A flash memory (256Mbits)
- ✓ The sensor: three axes for 14 bits at the frequency of 200 Hz
- ✓ Data transmission: 40Kbits/s

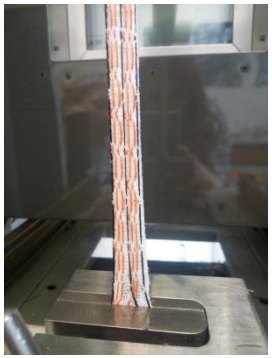
Intelligent wearable system: applications

Application 1:
Intelligent garment for remote diagnosis of pregnant women

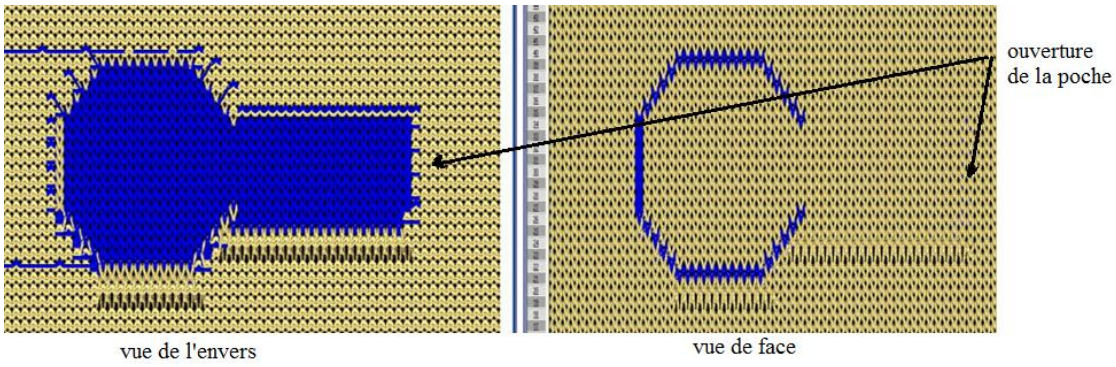
Textile and garment design:

- ✓ 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

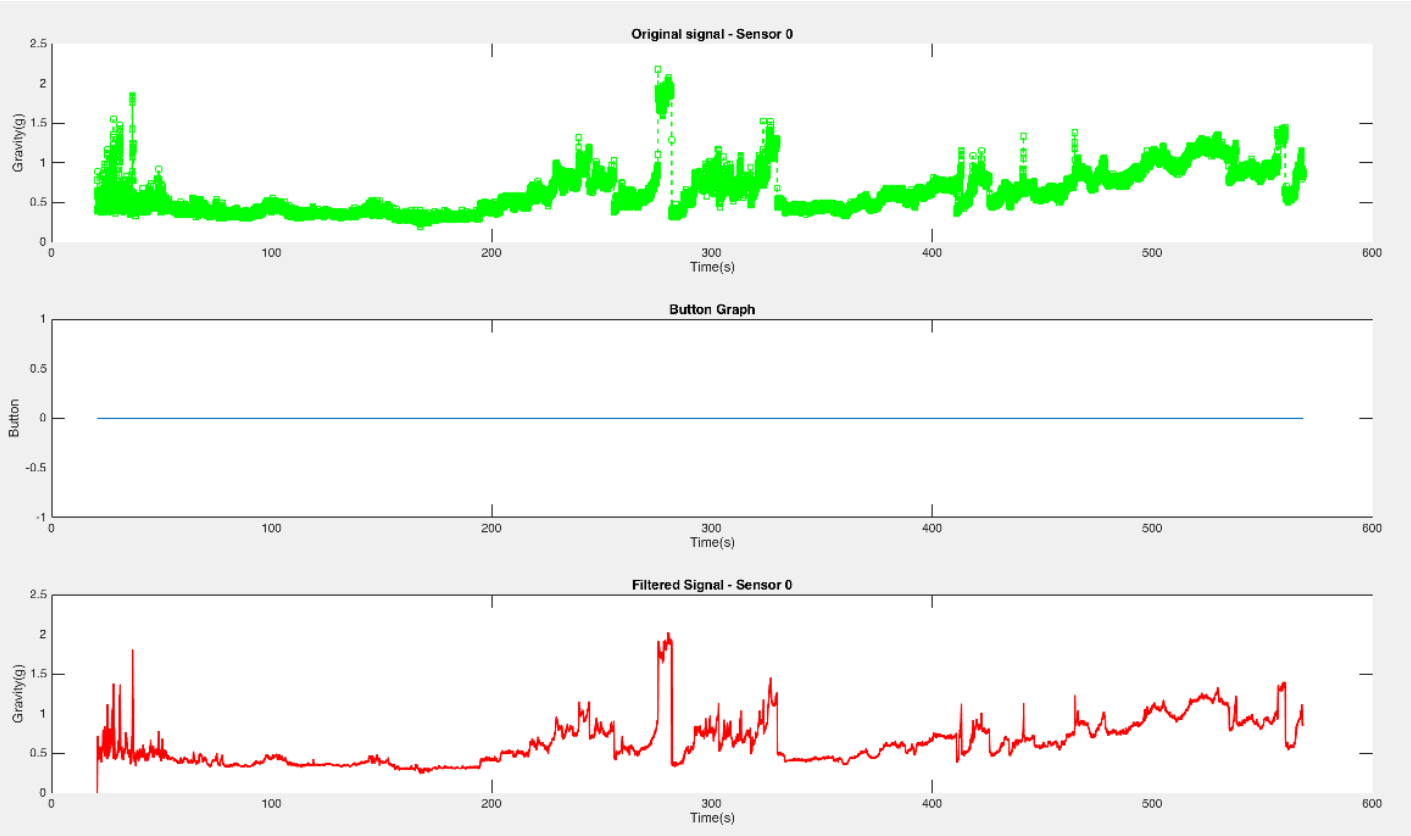
Modern network protocol

Mobile operating system compliance

Low power energy

Intelligent wearable system: applications

Application 1: identification of fetal movements

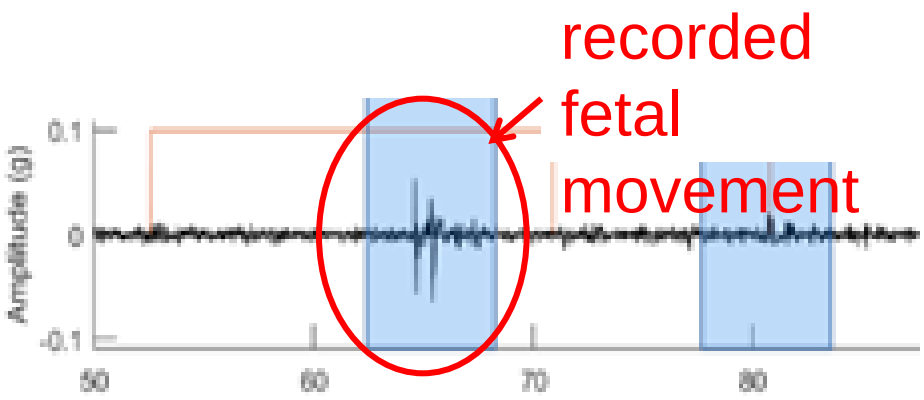


Original signal and signal filtered by wavelet analysis

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

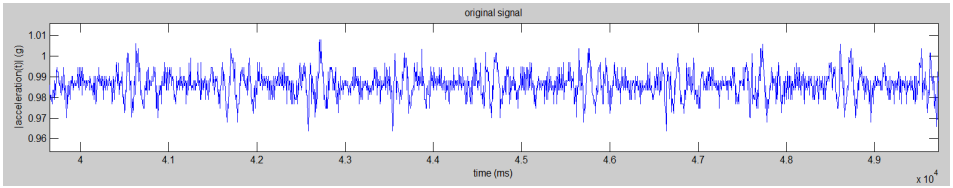
Total fetal movement counting since system startup

Instant view: Intensity for each fetal movement

Statistic view: fetal movement counting and corresponding intensity.

Intelligent wearable system: applications

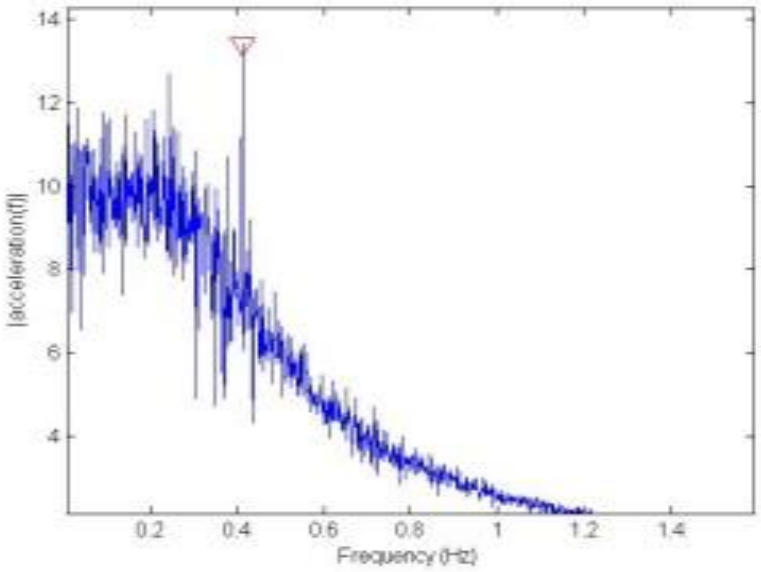
Application 2: identification of wearer's physiological signals



Raw signal

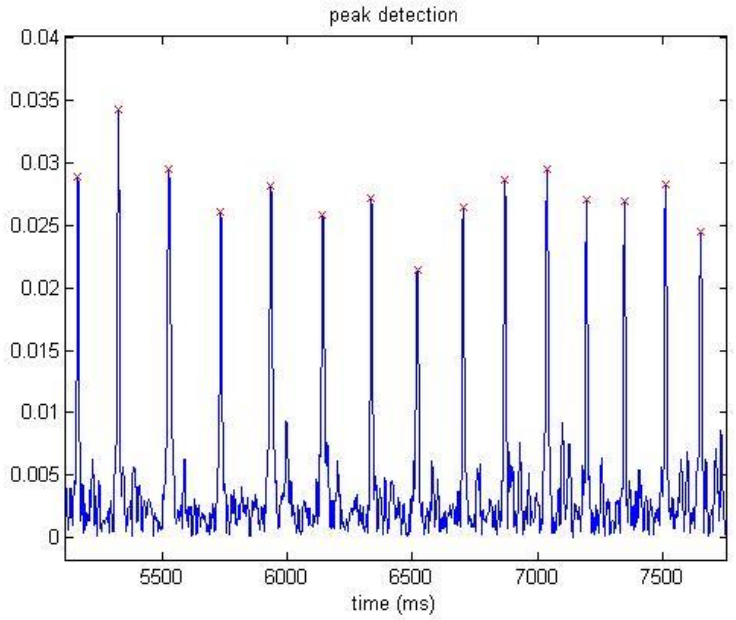
-Fourier
-Band filter (20/min)
-Peak detection

Respiration cycle



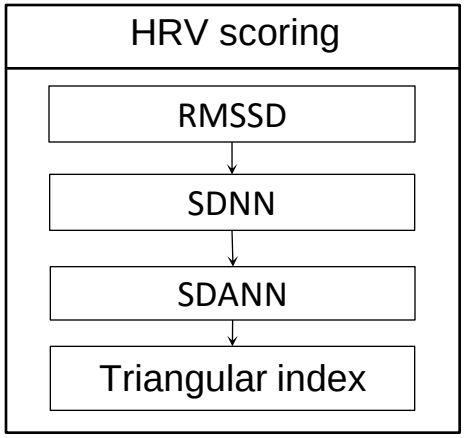
-Fourier
-Band filters

Heart Beat



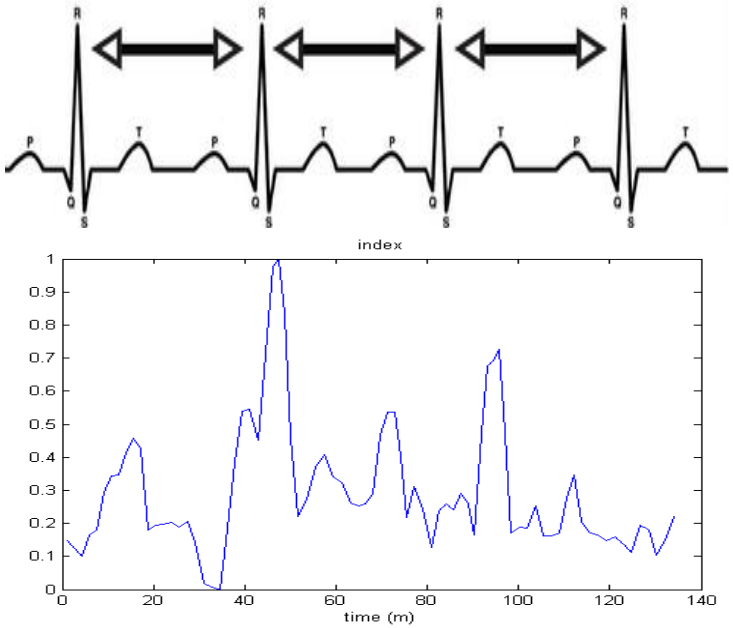
Intelligent wearable system: applications

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

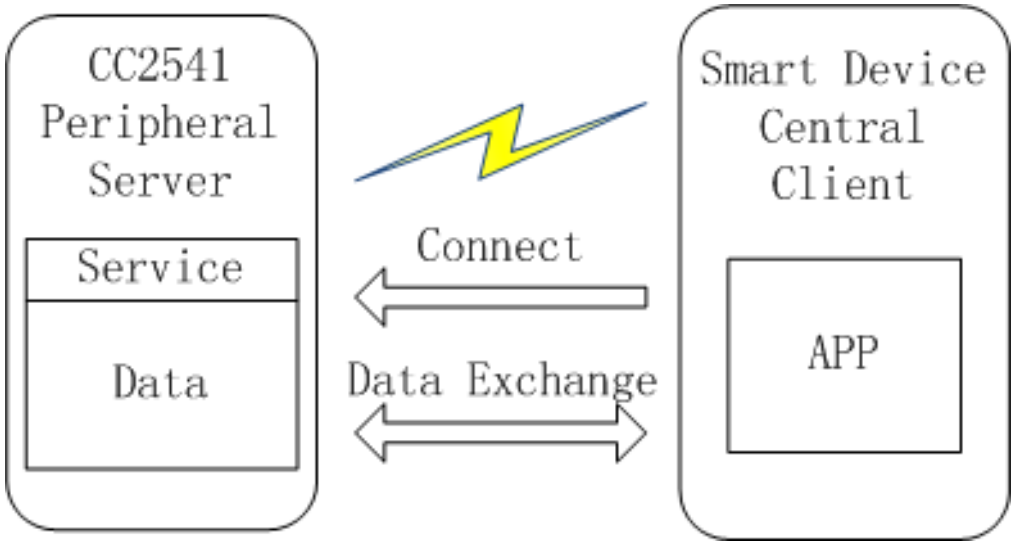


HRV triangular index (estimate of overall HRV): the integral of the density distribution divided by the maximum of the density distribution

Intelligent wearable system: applications

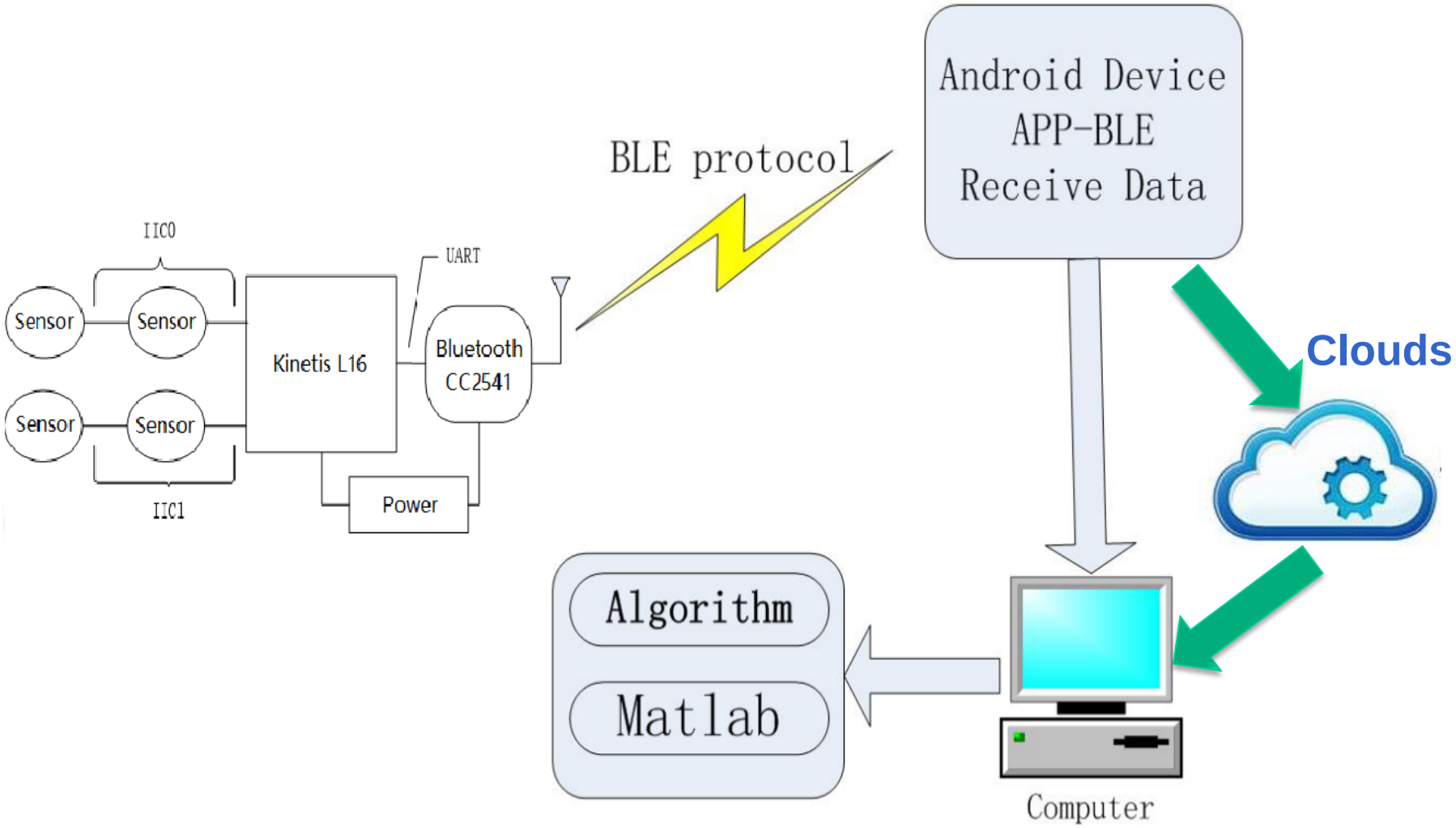
Communications:

- 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)