Smart textiles for leisure, professional and healthcare applications: an introduction to wearable systems based on CSEM participation to EU projects

Jean Luprano
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jean.luprano@csem.ch
www.csem.ch
Outline

- Introduction to CSEM – Swiss Centre of Electronics and Microtechnology
- Wearable systems and textile applications
- From “common” monitoring systems to smart sensors and applications
- Combination of sensor signals
- Leisure, sports, healthcare and professional applications
- Common monitoring, biochemical monitoring and biosensing
- Probing the future
- Conclusion
CSEM

… is a research and development company, active in the domains of micro-, nano- and information technology

… is a private company, with mainly industrial, but also public shareholders, not-for-profit

… is under contract by the Swiss Government to perform a special mission in micro- and nanotechnology

… has revenues of 37 M€, 380 employees, 5 centers in Switzerland & international activities
CSEM – our mission

Adding Value to Research

Mission of CSEM

Mission of Universities

Mission of Industries

TECHNOLOGY PUSH (Valorization)

MARKET PULL

Education Research Industrialization of Technologies Product Development Markets
Our Technology Platforms

- Microtechnology
- Microelectronics
- Photonics & Optoelectronics
- System Engineering
- Information Technology
- Nanotechnology
- Microrobotics
From Customers ...
Geographic Extension

CSEM Centers in Switzerland

- Thin optical films
- Microelectronics
- Microsystems technology
- Nanotechnology & Life Sciences
- System Engineering
- Time & Frequency

- Microrobotics
- Photonics
- Nanomedicine

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Our Partners

CSEM’s International Network

[Map showing CSEM’s international network with partners such as Tyndall, IMEC, Far East, Middle East, Brazil, and others.]

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Introduction

**Systems Engineering framework**

Success factors

- Reliability
- Comfort
- Low cost (reimbursement)
- Connectivity

Enabling technologies

- Advanced sensing and signal processing
- Miniaturization
- Low consumption electronics
- Wireless communication
- Multidisciplinary coordination
Wearable applications

- **Leisure and fun**
  - MP3, keypad
  - Flexible display

- **Sports**
  - Activity
  - Distance, speed
  - Heart rate

- **Professional**
  - Heart rate
  - Respiration rate
  - Body temperature
  - Location
  - External gasses and temperature

- **Health / telemonitoring**
  - Electrocardiogram
  - Heart rate
  - Respiration rate
  - Body temperature
  - Oximetry
  - Activity
Commercial products in sport

Sources: Adidas-Polar and Nike-Apple
Sports application – PULSEAR

- Pulse rate measurement device with no external probe such as chest belt
- Ideal combination for sports and entertainment (MP3) application
- Opto-inertial photoplethysmographic measurement platform (CSEM patent)
- Sensor and signal processing integrated into commercial earphone
- Validated real-time prototypes, referred to POLAR like devices
- Product development in process
On-body acceleration feature extraction and classification

Activity classes:
- Resting
- Walking
- Walking upstairs
- Walking downstairs
- Running
- Lying

Running speed estimation
- Comparable to GPS

Running efficiency feedback
Human kinetics – ActiSmile

- Health promotion tool on physical activity
- CSEM’s proprietary real-time classification algorithm on daily physical activity
- External data visualization and validation software (SFOS)
- USB and wireless Bluetooth version for data transmission
- Production for German insurance company and retail (e-shop)
- Future feature extension with energy expenditure
Multi-parameter monitoring device for astronauts

Intelligent and comfortable multi-parameters monitoring system

- ECG with dry electrodes
- Location independent SpO₂
- Respiration and activity monitoring
- NI Blood pressure
- Body core temperature on thorax
- Wireless communication to base station
- Clinical long-term test @ Concordia Base Station, Antartica
Protection e-Textiles aiming at:

- Fires
- Earthquakes
- Floods
- Terrorist incidents
- Major transportation accidents
- Major industrial accidents
- Chemical incidents
- Nuclear incidents
Medical wearable systems

Sources: Vivometrics and Verhaert
Wearable Health System

- **Small and Lightweight**
  Only 145g, small PDA size

- **Easy user interface**

- **Data transmission over GPRS link**

- **Sensor interfaces** for:
  - 5-lead ECG
  - Impedance measurement (respiration)
  - Piezo-resistive bands (movement)
  - Skin temperature
  - Standard oximetry sensor
  - Integrated accelerometers

- **Signal processing**
  - Heart rate
  - ECG enhancement

- **Powered by a Li-Ion battery**
  - Autonomy up to 4 hours with real-time streaming of all signals over GPRS

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MyHeart system

• **Acquired signals**
  - 3-lead ECG (5 and 6 elec.)
  - 1 impedance cardiogram (ICG)
  - 1 respiration by impedance
  - 1 respiration by piezo-resistance
  - 1 skin impedance
  - 3D or 2x2D accelerometers
  - 1 respiration sound
  - 32 strain resistance

• **Communication**
  - Download of stored data and streaming mode over Bluetooth
  - Link with mobile phone or PC

• **Size**
  - 88 x 67 x 18 mm
  - 100 grams (incl. battery)

• **Generic processing modules**
  - HR, RR, HRV features
  - BR, BA features
  - ACC fo, power, motion index
  - Activity classification
Textile platforms

- Second skin
- Catsuit
- Long-sleeve shirt
- Bed sheet
Examples of wearable electronics
Interfacing with electronics

- Interconnections between:
  - Textile sensors and garment
  - Microcircuits, keypad or flexible display and garment
  - Flexible battery, energy scavenging and garment
  - Optical fibres and electronics
  - Garment and wearable electronics
Common technical challenges of wearable systems

| Electronics is hard and thick | Textile is soft and elastic |
| Electronics is dense          | Textile is washable        |
| Electronics is localized      | Textile survives tears     |

**Make electronics:**
- Small
- Communicating
- More flexible, stretchable
- Redundant
- Re-configurable
- Context aware
- Robust

**Make:**
- Operation and use evident for the user
- Operation personalized
- Results trustable for the professional
- Data transfer confidential and secured
- Ensure interconnectivity
- Sensor washable, electronics detachable
Development & Integration of innovative sensing, MNT, textile and ICT towards functionalised Smart Fabrics and Interactive Textile

- Nano-engineered surfaces
- Conductive fabrics
- Micro-interfaces

Micro-systems physical sensors (attitude, fall, health…)

Flexible displays

- Point of care
- Micro-communicating: sensor interface, processing and wireless

- Micro-energy generators
Sensors for Sensing Textiles

- Physiological sensing and biosensing
  - Physiological sensing
  - Wearable patches performing biosensing
  - Combination of physiological and biochemical sensors
  - Combination of physiological and biosensors in a single garment

- BIOTEX project
  - Sweat measurements
    - pH, sweat rate, electrolytes
  - Blood measurements
    - Oximetry, pH, proteins
Wearable Biosensors – Wound Healing

• Integration of health monitoring tools into textiles, for safety and comfort
  • remote diagnostics to improve early illness detection
  • real-time remote monitoring of vitals signs, e.g. for sports, elderly, and professionals

• Monitoring Wound Healing – so far
  • Clinical evaluation (visual), analysis of wound exudates
  • Optical sensors for evaluation, but no tool for real-time monitoring!

• Continuous, *in situ* monitoring of wound healing progress
  • Local measurements in wound exudates
  • Severe burnt patients, chronic wounds (e.g. ulcers)
  • Target parameters: pH → stage of wound healing, infection type
    C-reactive protein (CRP) → acute infections, alarm
Biosensor for wound healing

Changes in the refractive index of the polymer layer or at the interface are monitored optically using the evanescent field of light propagating along a waveguide. Optical detection of refractive index changes, illuminating the waveguide with white light (LED) and detecting the wavelength of the outcoupled light with a spectrophotometer.
Conclusions

• Garments are a second skin to us

• Smart garments provide new means to interface the user with the environment and his body
  • Applications in leisure, sports, healthcare and professional security

• Textile sensors provide easy to wear sensors; they require more processing

• Combination of information from different sensors and advanced signal processing allows the extraction of sufficiently selective and reliable information from the raw signals

• CSEM is performing developments for industrial textile-based products, based on its background and experience in Smart Fabrics and Interactive Textiles (SFIT)
Thank you for your attention.

Jean Luprano
CSEM SA
jean.luprano@csem.ch
http://www.csem.ch/sfit