

LAAS Days  
Research & Technology


## An embedded instrumentation approach for detecting the fragility of complex systems

TICS/ S4M « Smart Sensing and SystemS Monitoring »

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## Smart sensing methodology




- > A Need for « Complex system smart monitoring » in spite of global modeling because systems are
  - heterogeneous
  - strong and robust enough to support damages so that defects take time to appear
  - their environment and use conditions are not deterministic
- > One way is « SMART instrumentation »
  - Design / assembly a node architecture capable of detection / analysis / information transmission
    - Using/adapting of sensors on shelves but using them in a different context
    - Manufacturing elements / layers / sensors based on micro/nano technologies
    - Developing a patch approach to place on / in the structure to be observed
  - Search for "signatures" of behavioral evolutions by combining signals (accelerometer, piezo, magnetometer) resulting from the propagation of mechanical waves for « immobile systems » or displacement for « mobile » systems
  - Implement algorithms to reduce power consumption using versatile architecture

→ to detect fragility or more precisely the level / risk of fragility


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# Smart sensing applications

**In-Flight Propeller Control**




**Fast Vehicle Diagnostic System**



**SMART Blade Recorder: M. Lastapis 2012 Thesis**


**Smart Patch : B. Hajjine 2016 Thesis**




**Method for detecting the fall of a human subject and corresponding actimetric device**  
WO 2016073013 A1

**LADEPECHE.fr**


Foix. Prévenir l'errance et les chutes des personnes âgées




**SMART SOIL MOISTURE: J. Roux Thesis 2017**



**SMART SOLE : Y. Charlon Thesis 2014**




**SMART Cycling: A. Bouillod Thesis 2017**



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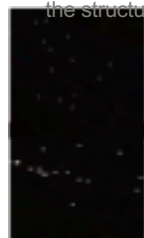


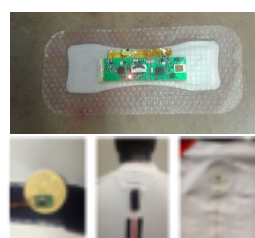
# Smart sensing: above or inside?

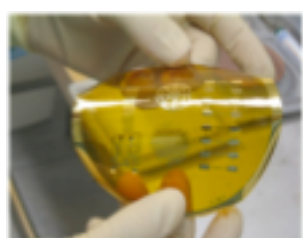
> Technological constraints

- Smart node take the measurement closer to the structure
- Smart node do not modify structure behavior
- Smart node could be above or inside the structure









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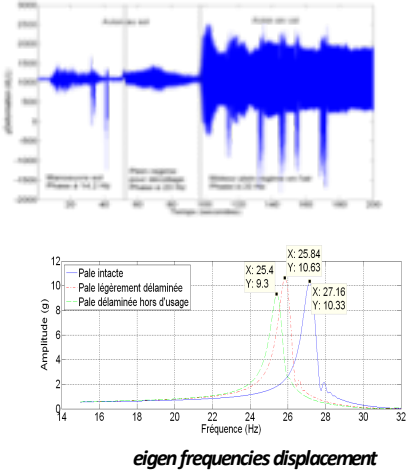
surface measurement  
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## Smart sensing: looking for signature

> Methodology approach

- ❑ Observation of the self intrinsic activity generated by the system (movement, vibrations, displacements...). Note that for static system (air plane, soil...) the piezo car generate stimuli)
- ❑ Computing of signature (based on spatio temporal behavior and/or statistical approach)
- ❑ Tracking temporal signature evolution (quick and/or slow drift)



The top graph shows two time-domain vibration signals. The bottom graph is a frequency spectrum plot of Amplitude (g) vs. Fréquence (Hz). It shows three distinct peaks corresponding to different states of a composite plate:

State	Frequency (Hz)	Amplitude (g)
Pale intacte	25.4	9.3
Pale légèrement délaminée	27.16	10.63
Pale délaminée hors d'usage	25.84	10.33

*eigen frequencies displacement*

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## Our partners



**Univ. Lorraine**  
Détection informatisée  
Endommagements  
ouvrages d'art

**cea tech**  
**lira**  
Imagerie pour le SHM  
Ondes guidées  
structures aéronautiques

**iemn**  
Institut de Mécanique et d'Ingénierie  
Méthodes de Modélisation et d'Analyse

**ARTS ET MÉTIERS Paris Lodron**  
École nationale supérieure d'arts et métiers  
Algorithmes de contrôle actif

**om**  
Architectures reconfigurables

**ESG**  
Ecole Supérieure de Génie

**CND**  
Mesures ultrasons

**im**  
SHM, Energy Harvesting

**ECOLE CENTRALE LYON**  
Matériaux composites

**ati**  
Nouveaux Matériaux SHM


**IBUS**  
EAD

**LIRMM**  
Technologies et Mems

**IPSTAR**

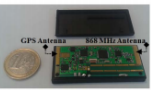
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## Focus on human direct sensing

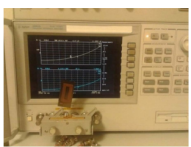
**AIM:** Mobility & gait sensing and analysis with a wearable patch  
**METHODS:** Printed coil for wirelessly charging and integrated sensors

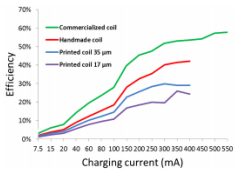


GPS Antenna  
868 MHz Antenna

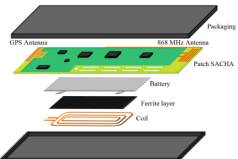


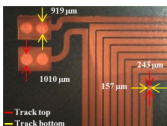
Charging pad



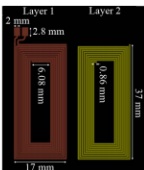



Charging current (mA)	Commercialized coil	Handmade coil	Printed coil 95 μm	Printed coil 17 μm
7.5	~5%	~5%	~5%	~5%
15	~10%	~10%	~10%	~10%
30	~20%	~15%	~10%	~10%
60	~40%	~25%	~15%	~10%
120	~55%	~35%	~20%	~10%
240	~65%	~45%	~25%	~10%
480	~70%	~50%	~25%	~10%
960	~70%	~50%	~25%	~10%





Track top  
Track bottom






Compromise between reduced size and operational autonomy.

**APPLICATIONS:** Fall detection and localisation for frail people

Collaboration Industrial

B.Hajjine et al. "Development of an electronic patch for falls detection and elderly tracking", International Conference on Biomedical and Health Informatics, Haikou (China), 2015


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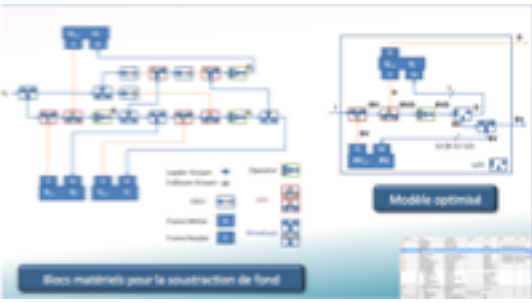


## Focus on human indirect sensing

**INDIRECT sensing:**

- > Detection of critical human postures based on multi-cameras
- > Algorithmic Integration on FPGA-based platforms for real time applications





Blocs matériels pour la soustraction de fond

MEMBRE ASSOCIÉ DU COMITÉ D'ÉVALUATION DES RECHERCHES  
 Directeur scientifique adjoint et responsable des équipes de recherche en informatique, Université de Technologie de Compiègne  
 Directeur scientifique adjoint et responsable des équipes de recherche en informatique, Université de Technologie de Compiègne

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## Focus on human indirect sensing

**AIM:** Continuous measurement of stride & speed walking with accuracy  
**METHODS:** Sensors integration in a 3mm thickness shoe insole and embedded algorithm development

**APPLICATIONS:** Frailty monitoring of the old people *Collaboration CHU and Industrials*

A. Piau et al. "A smart insole to promote healthy aging for frail elderly individuals: specifications, design, and preliminary results", JMIR Rehabilitation and Assistive Technologies, Jan-Jun, 2 (1), 2015  
 Y. Charlon et al. "Smart insole for measuring actimetry of trail peopleMed-e-Tel 2015"

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## Focus on human direct sensing


**AIM:** Biomech, physio & aéro sensing and analysis for performance monitoring  
**METHODS:** Smart integration on both wearables and bike components

Compromise between reduced size and acceptance "during competition".

**APPLICATIONS:** High potential athletes detection, performance improvement and injury prevention *Collaboration Pro cycling team*

A. Bouillod et al.

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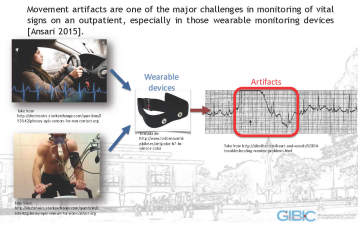
## Focus on human direct sensing

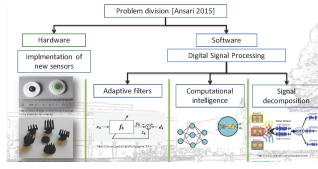
  

**AIM:** physiological sensing (with MA reduction) for common life activities

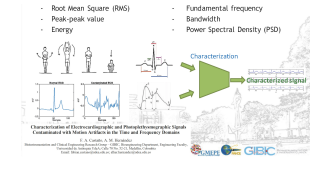
**METHODS:** Smart integration on both wearables and connected devices

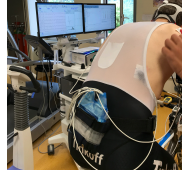
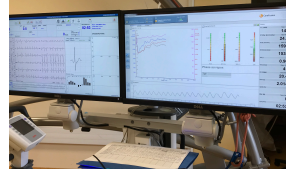
Movement artifacts are one of the major challenges in monitoring of vital signs on an outpatient, especially in those wearable monitoring devices [Ansari 2015].





- Root Mean Square (RMS)
- Peak-peak value
- Energy
- Fundamental frequency
- Bandwidth
- Power Spectral Density (PSD)



Compromise between acceptance signal processing complexity.

**APPLICATIONS:** Health monitoring (ECG), risk prevention

*University/hospital collaboration*

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