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Télévigilance médicale dans le contexte de la E-Santé. Evolution vers des approches de type Living Lab

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Under close cooperation with :

- SAMU-92/ APHP : Dr. M. Baer (MD), Dr. A. Ozguler (MD)
- APHP-Hôpital Broca, Paris : Prof. A-S. Rigaud
- CHSF, Corbeil : Dr. P. Dupont
- Telecom EM : Prof. G. Dubey, Prof. N. Djaidj

- UTC Compiègne : Prof. D. Istrate, Dr. T. Guettari
- Télécom ParisTech : Dr. G. Chollet, Dr. P. Milhorat
- LEGRAND, Limoges : Mr. P. Doré
- IBISC univ. Evry : Prof. E. Colle
- ASICA-France : Mr. O. Voltz

- Univ. Innsbruck-MCI : Dr. S. Schlögl
- UFES Vitoria – Brazil : Dr. R. Andreao
- UFC - Dr. P. Cavalcante, C. Magno, Prof. J.C. Moura-Mota

Remote Home Health monitoring

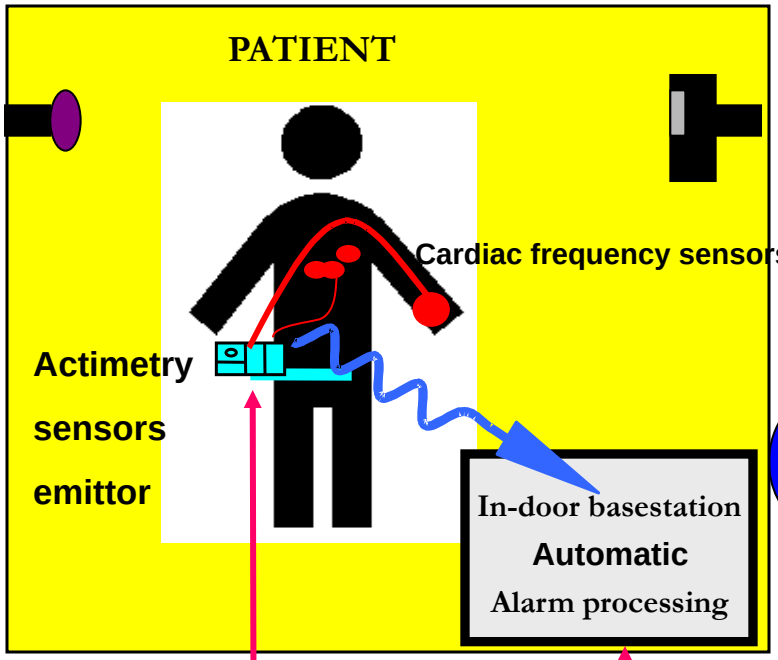
- **« Televigilance » ⇔Remote Health monitoring for Patients at Home (SAMU):**
  - For elderly persons with or without particular diseases (cardio-vascular, chronic diseases, frailty status…)
  - Feeling more secure and keeping their social link through connected communication services (call center presence)
  - Releases Hospitalisation load and possibly avoids evolution to Frailty

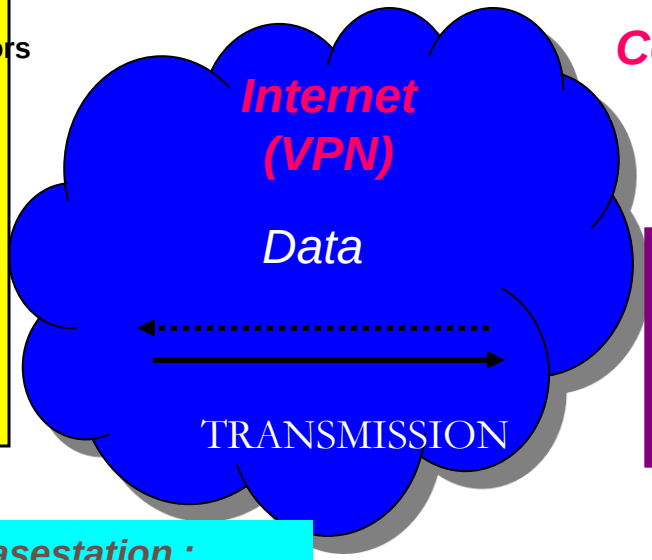
- **<u>Home in-door devices</u> connected to centralised Healthcare services:**
  - *Fall detection* Ambulatory Terminal worn by the user (mobility at home)
  - Fixed actimetry sensors (*Infrared*, *Sound*) with potential link to assistance robots (*Companion type*), placed in the home environment
  - Connected to remote Healthcare servers

PARAMETERS & PATHOLOGIES (Dr. Baer,SAMU-92)

Chronic diseases	Parameters
Diabetes : risk of hyper/hypoglycemia : risk of coma	Blood glucosis **Fall sensor**
Asthma, COPD : Acute asthma, Respiratry failure	Peak flow Sat O2
Hypertension	Blood pressure sensor
Cardio vascular diseases: Cardiac failure, (chronic, acute), Pulm. Oed, Coronary diseases, Arythmias, (flutter, AF), Atrio ventricular block,..	ECG, Sat O2
Stroke: risk fall, coma	**Fall sensor**
Parkinson disease: Fall risk	**Fall sensor**
Alzheimer's disease : Daily life accidents	**Fall sensor**, smoke & water detectors
Traumatisms	Alert, **Fall sensors**
Side effects of treatments (drugs used as routine or on demand)	ECG, Blood pressure, **Fall detection**

Remote monitoring system Architecture for Patient at Home





Centralised Servers

Medical surveillance centre

Pre-diagnosis

Doctor/Specialist

Diagnosis

Multi-sensors Terminal or ECG Holter (Design of sensors & conditionning)

<u>In-door Basestation :</u>
[Vital data fusion (signal processing)] + [automatic classification (HMM, EvN, Fuzzy Logic)]

Research areas in « Televigilance »

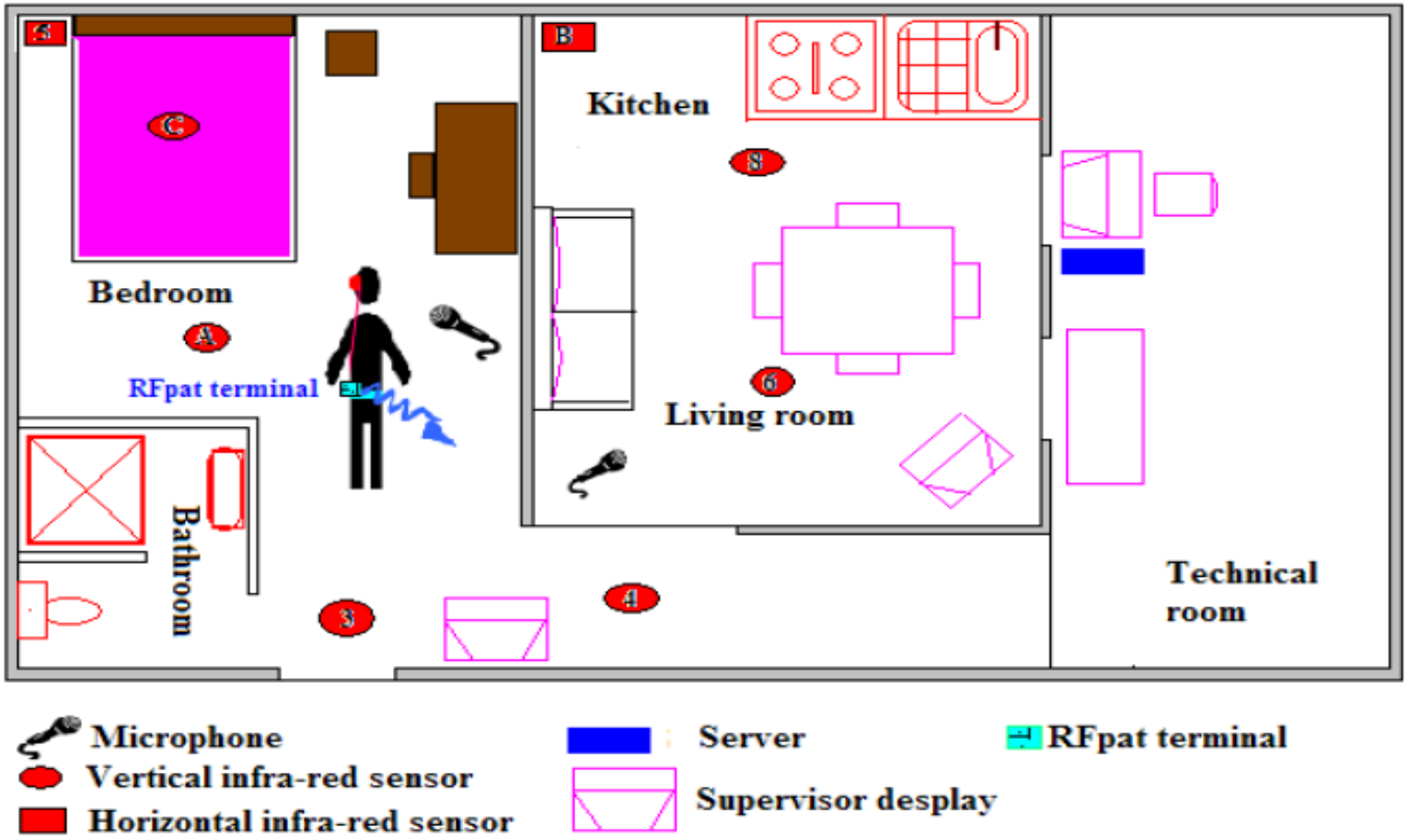
- **Multi-sensors Ambulatory Terminal on Patient [Baldinger-2004]:**
  - Automatic Fall detector and noise-robust vital signal extraction
- **Cardiac pathology detection [Andreao-2004]:**
  - ECG signal segmentation based on sub-beat Hidden-Markov Models
  - Ischemias and Arrythmias events classification
- **Alarm automatisation and context identification based on Data Fusion [Medjahed-2010], [Cavalcante-2012] and [Sehili-2013]:**
  - Physiological and actimetric data (cardiac frequency, movements,…)
  - Fall, posture or activity recognition
  - Contextual information (sounds, localisation, activity…) ANASON (D. Istrate-2004, Sehili-2012)
- **Voice-controlled man-machine interface for Elderly persons to the smart home environment => [Milhorat-2014, Chollet G. TelecomParisTech]**
- **Activity and sleeping monitoring in care-houses => [Guettari-2014 LEGRAND, CIFRE PhD]**

Ambulatory Terminal for fall detection, activities and vital signal monitoring

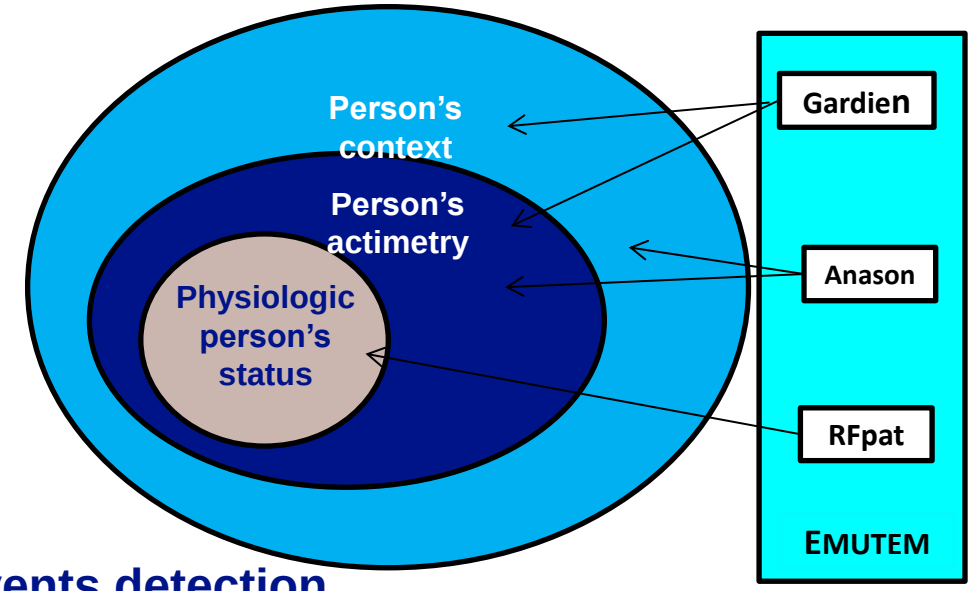
[Baldinger-2004] and IMT/Telecom SudParis PATENT

- Miniaturisation with ASICA for end-user trials in care-giver environment
  Combined with other modalities : IR sensors and Sound acquisition and detection systems
- Evaluated in Hospital environment (APHP)

Televigilance Lab in Telecom SudParis: technical validation using simulated habitation



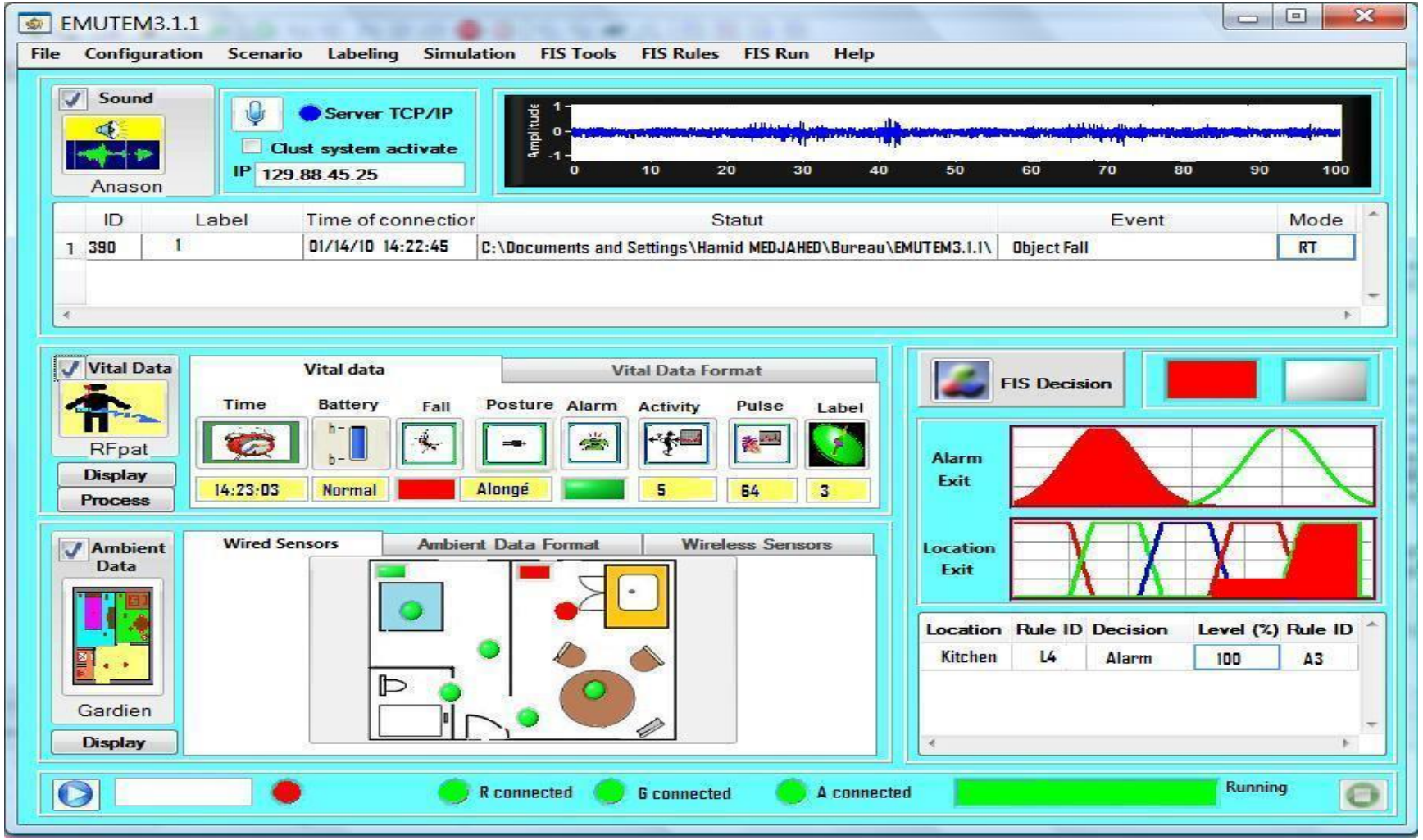
Modalities Complementarity and Redundancy



- **Improve Sensitivity and Specificity of Fall events detection**

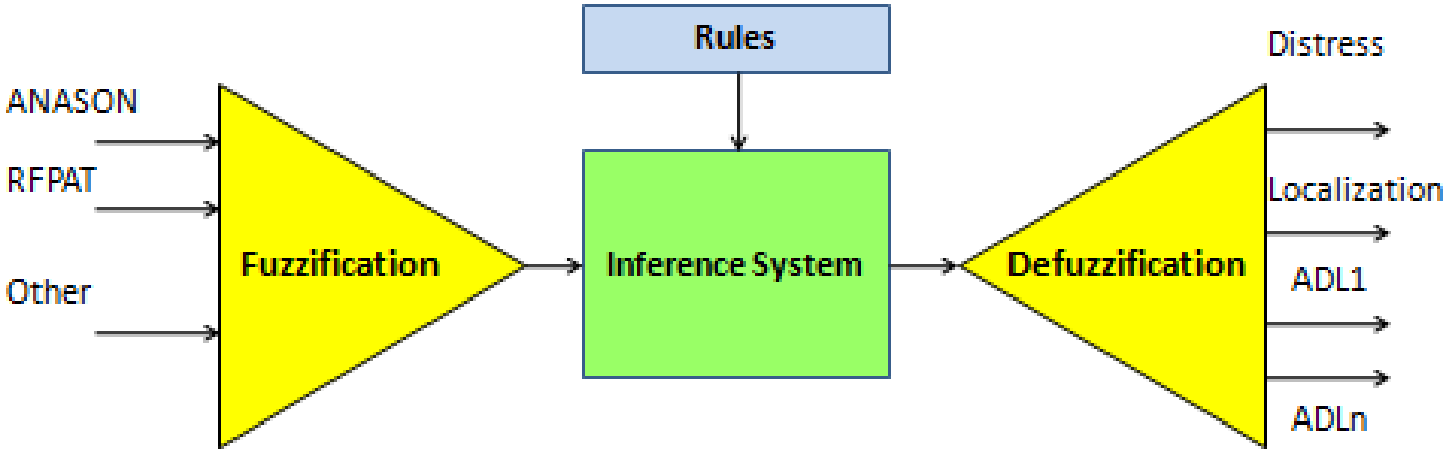
- **EMUTEM system [Medjahed-2010]**
  - Anason [Istrate-2004] [Sehili-2012] : Acoustic environement
    - Abnormal sounds and distress utterances analysis and pattern recognition
  - RFpat [Baldinger-2004] : ambulatory vital/movements signal (pulse)
    - Actimetry and Fall detection (accelerometry)
  - Gardien [Steenkeste-1998]: fixed Infrared sensors network
    - Localisation and actimetry of the person
    - Fall detection

Multimodal Fusion for Medical Televigilance [PhD H. Medjahed-2010]



Principle
(*Zadeh, Mamdani & Takagi-Sugeno*)

- ***Fuzzification*** of input data onto a fuzzy variables ensemble : belonging notion => *imprecision*
- ***Inference*** of algebric type (*T- et S-normes) of Data*
- ***Linear Combination*** (digital)
- ***Defuzzification*** of fuzzy ensembles generated by rules (inference step) into real values : e.g. by computing Gravity centre (COG) of the union of each modality fuzzy ensembles.



Fuzzy-logics-based Fusion - Performance [PhD-Medjahed-2010]

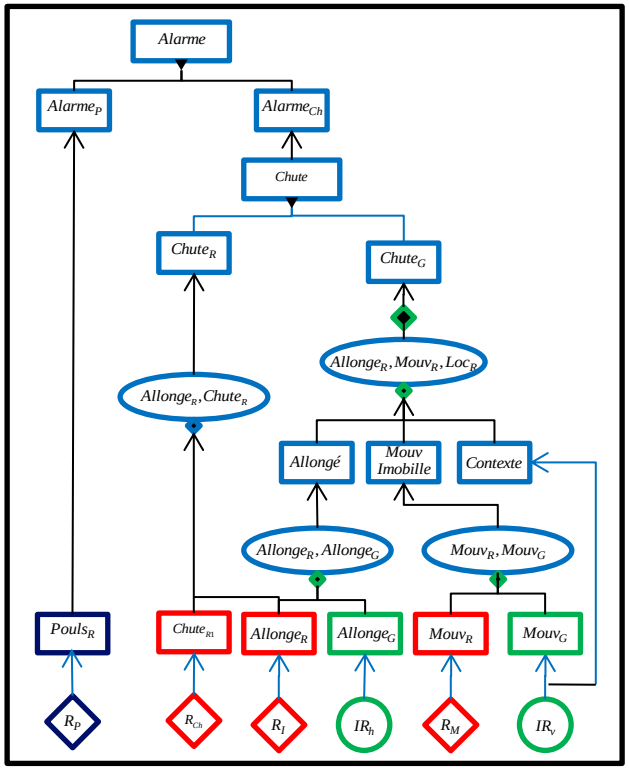
- **With simulated conditions (30 normal and 70 fall sequences):**
  - Sensitivity : 97%
  - Specificity : 96%

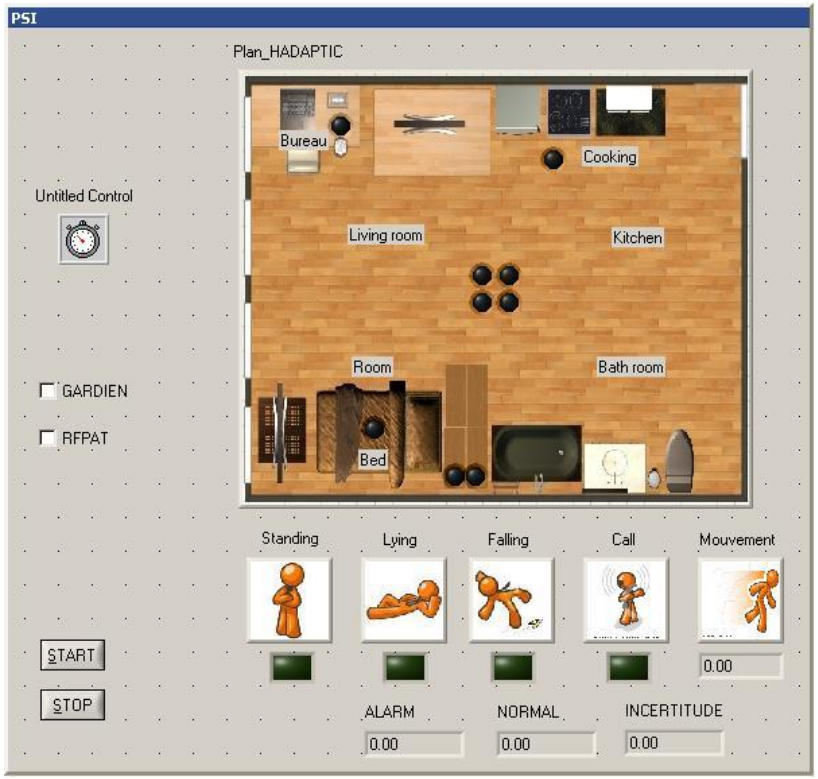
- **Under real conditions (recorded database with real actors) including 20 scenarios with 10 normal and 10 fall situations :**
  - Sensitivity : 90%
  - Specificity : 100%

- **Leads to introduce an *explicit dependence between data* by a *graphical approach***

  => e.g. Evidential Networks based on Dempster-Shafer Belief Theory

Evidential Network-based Multimodal Fusion for Fall Detection [PhD-P. Cavalcante-2012]

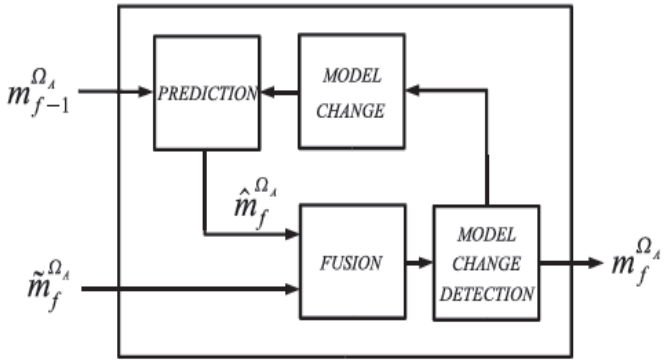




EVALUATIONS : Specific difficult distress scenarios (soft falls)

	Baseline	EN Fusion
Sensibility	75,76 %	93,94 %
Specificity	100 %	100 %

Comparative performance Static/Dynamic Evidential Networks [Cavalcante-2014]



Prediction : $\hat{m}^{\Omega_A}_{f,\mathcal{M}} = m^{\Omega_A}_{\mathcal{M}} \textcircled{\cup} m^{\Omega_A}_{f-1}$

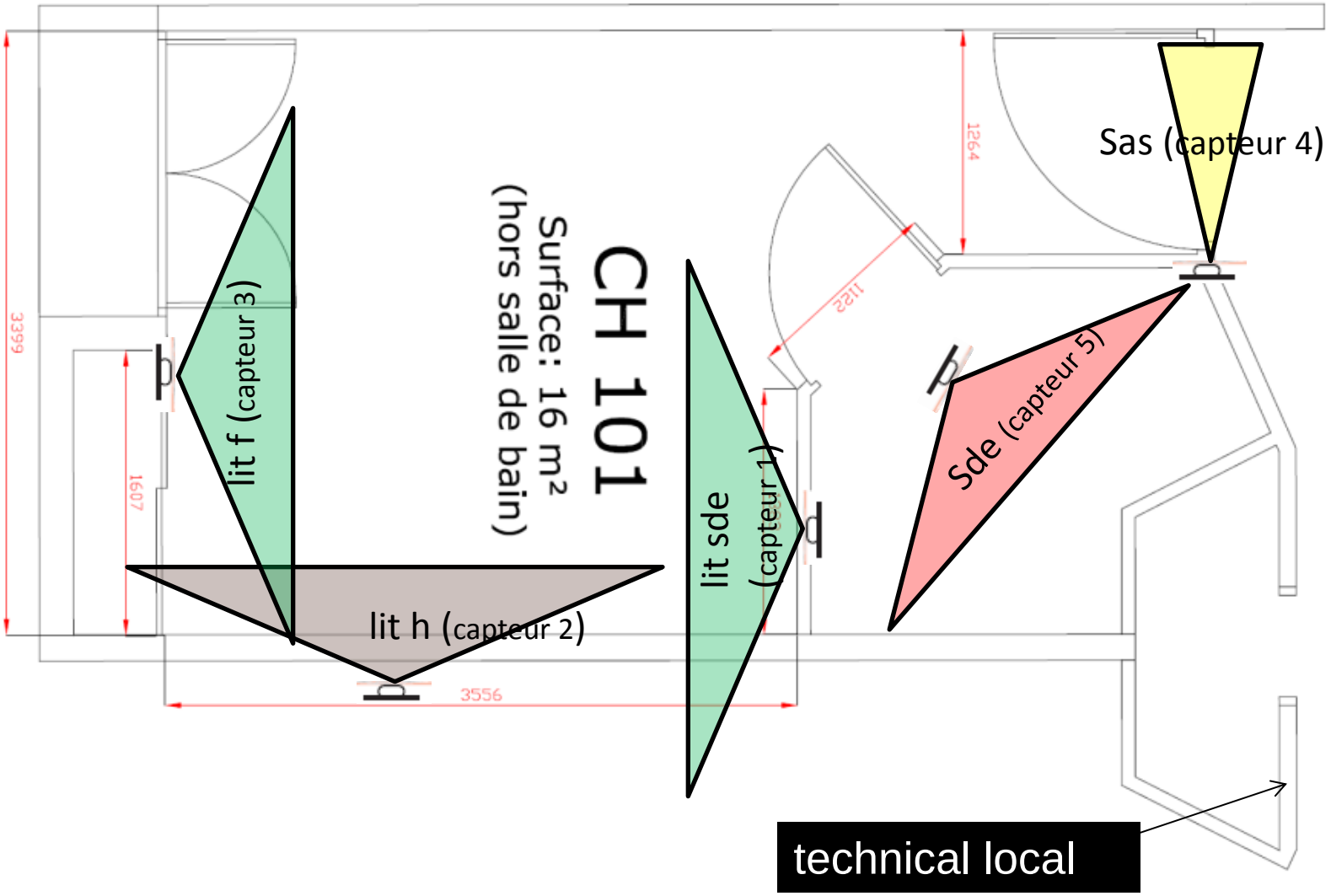
Conflict : $\epsilon_f = (\hat{m}^{\Omega_A}_{f,\mathcal{M}} \textcircled{\cap} \tilde{m}^{\Omega_A}_f)(\emptyset)$

Fusion :
$$m^{\Omega_A}_f = \begin{cases} \hat{m}^{\Omega_A}_{f,\mathcal{M}} \textcircled{\cap} \tilde{m}^{\Omega_A}_f & \text{if } \epsilon_f = 0 \\ \hat{m}^{\Omega_A}_{f,\mathcal{M}} & \text{otherwise} \end{cases}$$

Model update :
$$m^{\Theta}_{t,M} = \begin{cases} change & ,if \quad \epsilon_f \geq T \\ m^{\Theta}_{t-1,M} & ,if \quad \epsilon_f < T \end{cases}$$

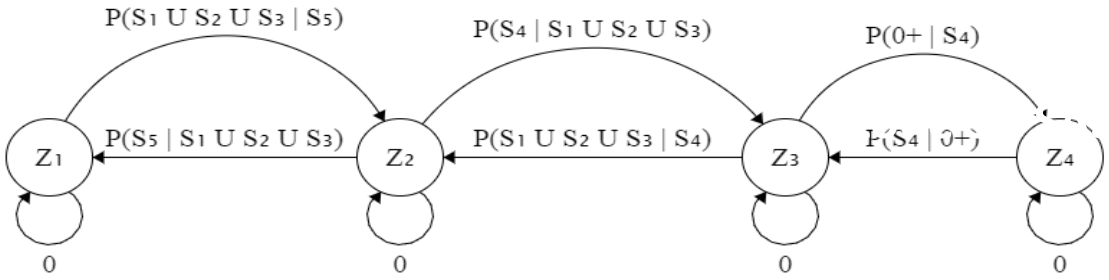
Performance	Fusion RE_{RG}	Fusion RED_G
Sensitivity	**94 %**	**97 %**
Specificity	**100 %**	**80 %**

EHPAD of Ambazac: pilot installation
(LEGRAND / CHU Limoges / Univ. Bourges-Orléans)



Localisation and unauthorised person detection [Cavalcante, Magno et al.-2015]

State model for actimetry



Resident /3rd party detection

- ZONES (Z)

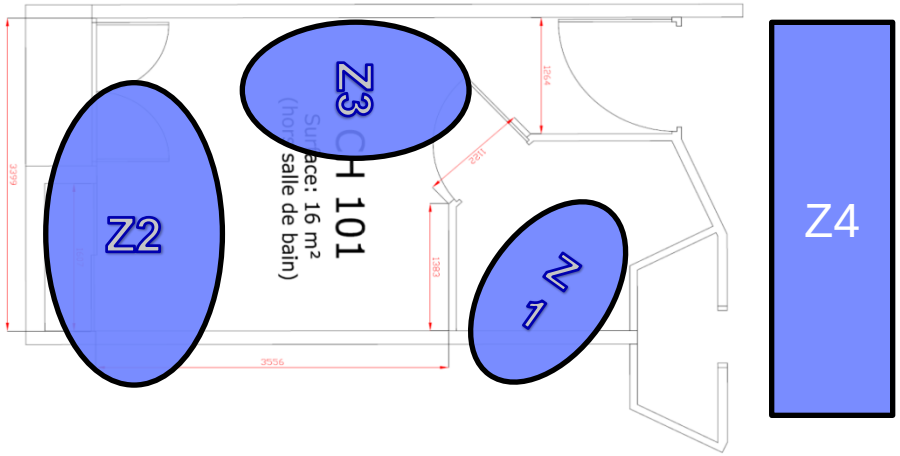
Z_1 - SdE
Z_2 - Chambre
Z_3 - SAS
Z_4 - Dehors

- PIR SENSORS (S)

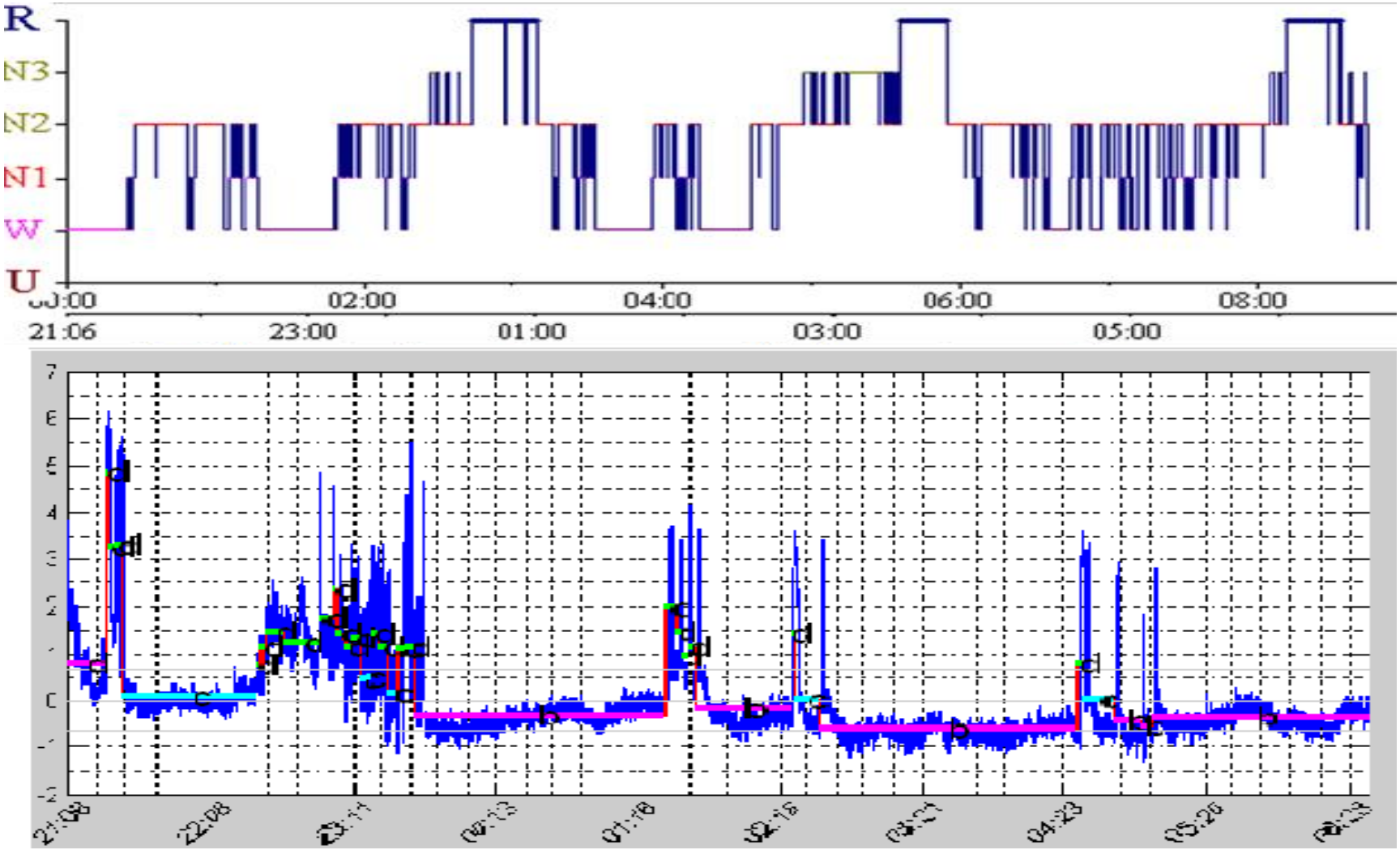
S_1, S_2, S_3 - Bedroom
S_4 - SAS
S_5 - SdE
0 - Absence of movements (inactivity)
0+ - Long time of d'inactivity

Module Response :

- Localisation of the resident (integer zone indicator)
- Actimetry of the care-receiver (excel log tabulated)
- Monitoring CR's I/O (tabulated - log)
- Presence of 3rd party by rupture detection of the inference model (of CR) (indexed in table)



Capteur thermique et qualité du sommeil [Guettari-PhD2014]



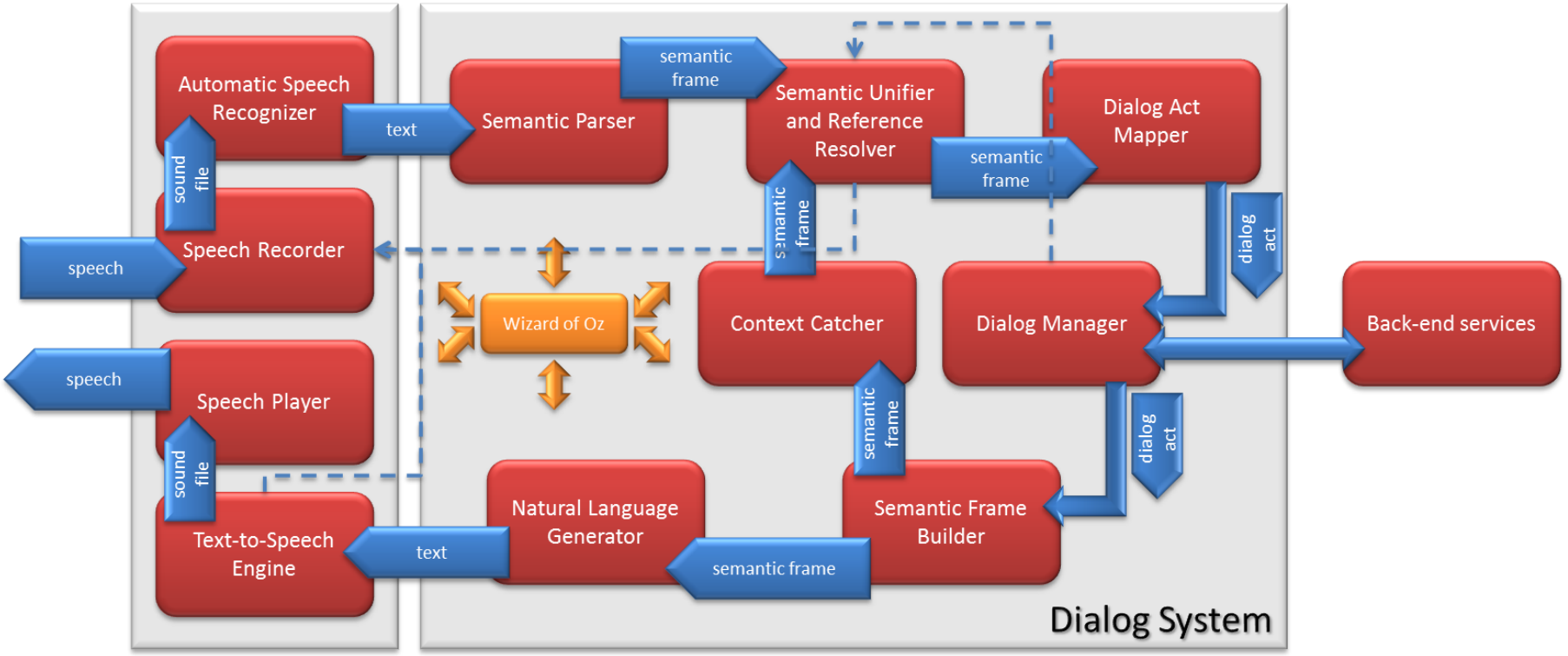
Companion Robots integrated into the smart home

•Voice-control access / Dialogue Management with Telecom ParisTech [PhD.Milhorat-2014]

•Sounds/speech combination [Milhorat-2013], [Istrate-2012]

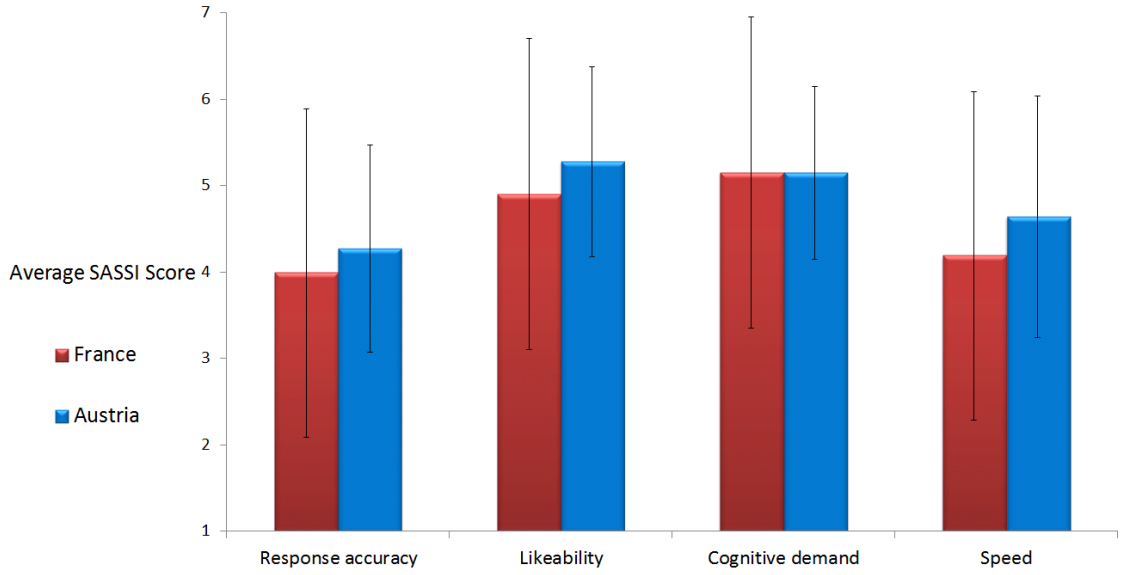
vAssist - Natural Interactive Voice Interface for Elderly : Open Dialogue Management platform

[Milhorat-PhD2014] [Schlögl-2014]



vAssist system evaluation

- **Subjective Assesment of Speech System Interface is especially dedicated to speaking interfaces evaluation.**
- **The user gives a mark between 1 (not like at all) à 7 (like very much) : *performance, confort d'usage, demande cognitive et latence.***



ICT systems for Healthcare and Well-being : Living-Labs: an effective Tool

- **Well-being at home and at Work :**
  - Healthy Lifestyle (ex: Philips)
  - Physical activities and sleep tracking (ex:Withings)
  - ADL, exorgames, monitoring the pre-frailty :
    - Programmes de recherche Européens H2020, AAL
- **Centres of expertise and evaluation in France:**
  - CNR-Santé : TASDA, STIMCO…
- **Living Labs in France and Europe:**
  - AutonomLab (Limoges), ActivAgeing (Troyes), LUSAGE (APHP), Hopidom (Lille), Gerhome (Nice)….
  - CASALA (Irlande), LL-Schwechat (Autriche), Amsterdam, i-Homelab (Aachen, 1st one!), iStoppFalls (Köln)…

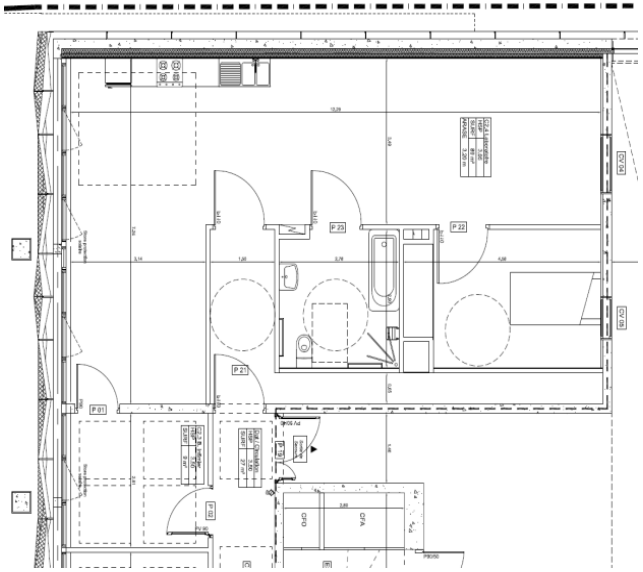
Evolution towards a Living Lab : « EVIDENT »

- **Life-space of co-design and test under development : « EVIDENT »**
  - « Espace de VIe Intelligent pour les personnes DépENdanTes, atteintes de limitation fonctionnelle »
- **Telecom SudParis and Telecom Ecole Management Research :**
  - oriented towards Healthcare and Dependence
  - with collaboration of IBISC/Uni-Evry
- **Rehabilitation, functional losses**
  - CHSF Hospital platform in Corbeil

Partnership

- **Coordination Team :**
  - Telecom SudParis (TSP)
  - Université d'Evry - Laboratoire IBISC (UEVE)
  - Telecom Ecole de Management (TEM)
- **Living lab 'Handicap et Participation Sociale'**
- **Hôpitaux Franciliens and Healthcare centres**
  - Hôpital SudFrancilien de Corbeil
  - ClinAlliance (Villiers s/Orge)
  - APHP Broca (maladies d'Alzheimer)
  - SAMU-92 (urgences et tele-alarme)
- **SME and Industrial companies:**
  - VigiFall
  - Auticiel
  - ASICA, Legrand,…

Living-Lab EVIDENT under elaboration

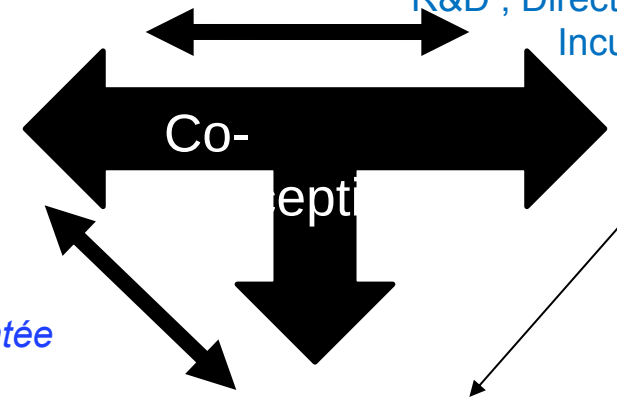


- **On-site evaluation in situation of using ICT devices**
- **Actuel Appartement**
  - Living-room, chambre, bathroom
  - Local for supervision
  - Integrated in MISS building on Campus of Telecom SudParis

A Research Community

Pôles de compétitivité : Cap Digital et System@tic
Alliance Big Data, Science Vie et santé
OpticValley

Evry Science et innovation; ENSIIE;
R&D ; Direction de l'innovation;
Incubateur …



- *Intermédia team ; EPH (Electronique & Physique) de Télécom SudParis.*
- *l'équipe IRA2 (Interaction, Réalité augmentée et Robotique Ambiante), IBISC, U. Val D'Essonne*
- *UCOTIC, sociologie et économie de la Santé, Télécom école de Management*

LL Handicap et participation sociale

Acteurs économiques du territoire …
- Repotel

Le service de réhabilitation fonctionnelle du CHSF

ARS IDF

Territoire Evry, Agglomération, Centre Essonne, Région IDF.

Potential Healthcare applications

- **Sharing experiences and expertises for research and development on Autonomy within the Evry area (South-east Paris) and within our TSP isntitute :**
  - Gait analysis (TSP)
  - Activities identification (TSP)
  - Analysis of behavioural signals for early pathologies detection (TSP)
  - Non invasive sleeping quality tracking (Legrand, UTC, TSP)
  - Sociology on usages and simulation (TeM)
  - Economy on innovation (TeM)
  - Ambient and Companion robotics (IBISC)
  - Functional deficiency Rehabilitation (CHSF)
- **Research Communauty, Methods, Tools sharing**
- **Thanks to « Espace de co-conception EVIDENT »**

Hôpital sud Francilien – Corbeil-Essonnes (Ph. Dupont, MD)

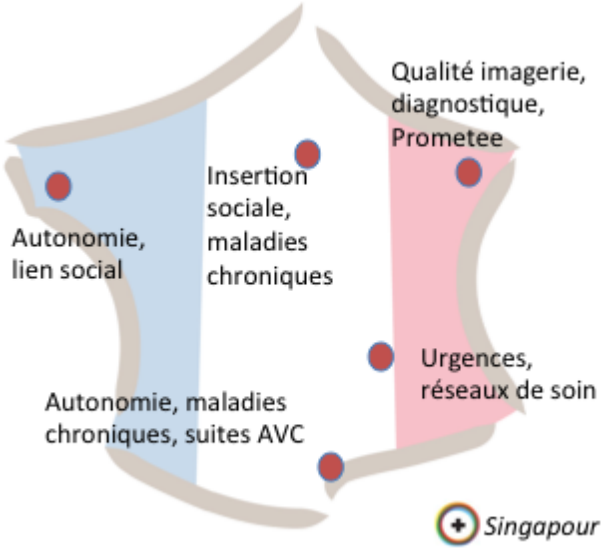
- **Hospital Service for physical medicine and functional re-education (MPR)**
- **Take in charge *physical deficiencies* and *balance troubles* after *cerebral vascular strokes* or after *human movement apparatus traumas***
- **Re-education under hospitalisation before come-back to Home of 300 patients per year (most live close to EVRY)**
- **Follow-up of hospitalisation in « day hospital »**

SHELL at Institut Mines-Télécom

Federation of Living Labs in Health, Autonomy and Quality of Life

B. Dorizzi – Dean of Resarch Telecom SudParis

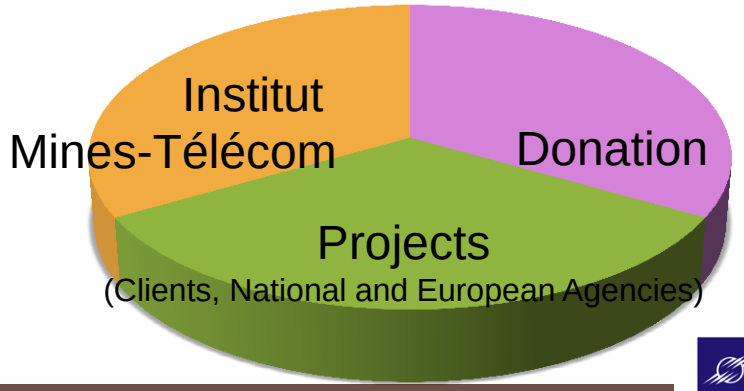
- ***Living Labs** of Institut Mines-Télécom*



- *Shell, **Interests of the networking***
  - **Act as a national and international leader**
  - **Pooling resources and best practices, foster collaborations**
  - **Facilitate the transition to innovation and value creation**

- ***Profits for** Institut Mines-Télécom*
  - **Helping to develop the industrial fabric in health and autonomy**
  - **Provide testing grounds to the researchers**
  - **Provide large ground truth databases to the researchers**
  - **Develop evaluation standards to validate research results**

- ***Business Model (funding)***



Conclusion and perspectives

- **E-monitoring solutions under fast growing :**
  - Several solutions but Market not yet developed
  - Well-being / Medical devices
  - Robustness and scalability
  - Data processing for Sleep quality for Frailty Prevention

- **Co-design and pilot evaluation through Living Labs will contribute to Innovation :**
  - Crossing various experiences and actors: healthcare, sociology, paramedical, ICT industry and research…
  - User- and Professional- acceptance
  - Economical model to establish
  - SME and Research labs towards innovation

Merci / Thank you

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