Intelligent medical devices and systems for telemedicine

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I. Introduction

- Health:
  - Worldwide major concern nowadays
  - Developed countries: increase of # of dependent people
  - Countries in development: insufficient access to health

- E-Health = ICT + Health
  - One of the main approaches to downscale health cost
  - Fifth axis of research of the SMART Labex for transversal applications

- E-Health and Computational Social and Behavioral Sciences
  - E-Health = application domain for Computational Social and Behavioral Sciences
  - Conversely E-Health research => tools for Behavioral Sciences

- Several case studies from projects of the SYEL research team of LIP6
Outline

I. Introduction

II. Implantable devices

III. “Medical device” certified image compression

IV. Telemedicine systems

V. Conclusions and perspectives
II. Implantable devices
Implantable devices

- Medical examines performed in specific conditions
  - Hospital, dedicated laboratories, etc

- **1st Issue: Bias**
  - Specific conditions ≠ from real life conditions => bias in the diagnosis

- **2nd issue: Cost**
  - Specific conditions => high cost of medical examines

- => Development of new sensors for the chronical acquisition of physiological signals to monitor functional activity of the patients in their everyday life

- Case study: implantable devices
  - 😞 Invasive, very long developments
  - 😊 Once implanted, people tend to forget them

- => Suitable for extreme cases:
  - Pacemakers
  - Deep Brain Stimulation for Parkinson therapy
Communicating implant for the multimodal imaging of the spinal cord
Pathologies of the spinal cord

- Public health problem

- Sclerosis
- Trauma
- Osteoarthritis
State of the art

Current technique

- Magnetic Resonance Imaging (MRI)
  - Insufficient for diagnosis and monitoring

Total immobility + Not chronic

Limited resolution + Physiological noise

Functional MRI during development

This area is it still functional?
In addition to structural imaging, doctors need an ambulatory measurement tool

- To evaluate the functional status of the spinal cord in the daily activity
- To establish prognostic of recovery
- To measure induced changes by
  - Pharmacological agents
  - Rehabilitation
  - ...

To understand
- The role of the spinal cord, functionning in interaction with brain
- Its degree of independence in some motor decisions or sensory interpretation
Objectives of SPINALCOM

- Development of a wireless implant to evaluate the spinal cord activity by measurement of:
  - The $O_2$ consumption by diffuse optical
  - (The electrical activity by ElectroSpinoGraphy)
  - → In fine: Network of communicating implants
The SPINALCOM project

- **Members:**
  - LIP6/SOC/SYEL: S.Feruglio, F.Vallette, O.Tsiakaka
  - LIB: H.Benali, A.Goguin
  - AP-HP: Pradat

- **Partners:**

- **Support:** SMART Labex and EDITE School of PhD students
History

- 2009-10: 1st Prototype with wires → Meas. on cats
- 2010: Patent (Goguin, Benali et al.)
- 2011: 1st RF wireless prototype at LIP6
- 2013: New prototype generation, tests on pigs
Many

- Digital oximeter systems
  - But implantable oximeter on simple artery is at the research level
- Informations about bones and brain

- However, few information about the spinal cord
  - Dynamic optical model is complex
  - No real functional information about the spinal cord

- Modeling of this kind of opto-electrical system in its environment has never been done
Preliminary results

- Prototyping

Study of new architecture for ASIC
4 responses in the same pixel
Preliminary results

- Spectral responses with spectrophotometer
  - Vertebra alone
  - On pig
    - In and out of vertebra with
Preliminary results

- Hemodynamic response of the spinal cord
  - In pig (T14)
    - In and out of vertebra → Demonstrate feasibility
Conclusions and perspectives

- Preliminary results are encouraging

- Long term research on implanted devices
  - Suitable for extreme cases:
    - Pacemakers
    - Deep Brain Stimulation for Parkinson therapy
    - Spinal cord injury

- Development of new sensors for the chronic acquisition of physiological signals to monitor functional activity of the patients in their everyday life
III. “Medical device” certified image compression
“Medical device”: the case of images

- Medical images are more and more used for diagnostic

- 1st Issue: Storage
  - Amazing increase of health data => need for compression

- 2nd issue: Quality
  - Diagnostic => data quality preserved through compression

- => Development of new algorithms for lossy image compression at diagnostic quality
  - Certifiable / certified as “medical device”
The WARM Project

- Objective: lossy compression of medical images sequences at diagnostic quality
- Participants from LIP6: Imen Mehdhbi, Khalil Hachicha and Patrick Garda
- Support: FEDER 2011 – 2013
- Other partners:
  - Companies: CIRA, PARTELEC
  - Laboratories: ETIS, HEGP
Sequences of 2D medical images

CT scan

IRM

Angiography

1000 slices

> 1GB

500 slices

> 1GB
Compressio of medical images: state of the art

Lossless compression

- Exact reproduction of original data
- Low compression rates: 3 : 1 to 6 : 1

Lossy compression

- High compression rates: 10 : 1 to 50 : 1
- Some informations can be lost through the compression / decompression process
Compression of medical images sequences: goal

How to compress sequences of medical images, at a high compression rate while keeping a quality sufficient for diagnostics?
State of the art

- JPEG et JPEG2000
  - With recommendations (ACR, HAS, etc) to prevent excessive image degradations
  - =>
    - Artifacts affect quality and could prevent diagnostics
    - Insufficient compression rates.
A specific coder: WAAVES

- Certified as a medical device for still images (CE)
- Compatible with DICOM
- Lossy compression at diagnostic quality with rates up to 90 : 1

Courtesy of Didier Heudes, INSERM / HEGP
MMWaaves: Mask Motion Waaves

- UPMC Patent with international extension
  - Method and device for processing image sequences with masking

- Waaves
  - Certified as a medical device for still images (CE)

MMWaaves = Waaves + UPMC Patent
MMWaaves

- Mask Motion detection
- Component Transformation
- DWT & Quantization
- Adaptive scanning
- Bit plane Coding
- HEC Coding

Reference

Image

Difference image

Motion detection

Movement bitmap

Masking

Masked Image

Compression

Waaves

Reconstruction

Image processing diagram with steps including motion detection, masking, and compression.

SMART LABEX

Institut des Sciences et Technologies des Médias de Sorbonne
Experimental results
Compressed size w/r to reference image update: CT

Slices displacement 1.2 mm → Reference stride = 32
Compressed size w/r to reference image update: angiography
Structural Similarity (SSIM) & Multi-scale SSIM (MS-SSIM)

Structural similarity of images more realistic than PSNR. Proposed by Didier Heudes, INSERM / HEGP.
MMWaaves & MLPWaaves

Radiography: lung

CT: brain

IRM: Knee

Coronary angiography
Two algorithms and software for the compression of medical images sequences
- MMWaaves: Gain in compression rate vs WAAVES et JPEG2000: 25% - 75%
- MLPWaaves: Gain in compression rate vs MMWAAVES: up to 40%

Evaluation of the medical images quality
- SSIM > 0.98

Feasibility of lossy compression of medical images at diagnostic quality

However medical validation yet to be achieved
IV. Telemedicine: Smart-EEG
Telemedicine

- Issue: access to medical experts
  - Developed countries: older population, less experts
  - Countries under development: few medical experts

- Telemedicine: Distance access to the medical expert thanks to ICT
  - Medical examine performed locally by technician or nurse

- Diagnostic requires transmission of physiological signals + audio-video of the examine performance

- Difficult diagnostic cases require precise synchronization between physiological signals, audio and video
Smart-EEG: System for Acquisition and Transmission of Multimodal Synchronised EEG

UPMC/LIP6/SOC/SYEL participants: Laurent Lambert, Zyled Ahmed, Mohamed Shaaban, Imen Dhif, Andrea Pinna, Khalil Hachicha and Patrick Garda

Other partners: ACACIA, CIRA, PARTELEC, 2CSI, ETIS, HEGP, Lariboisière Hospital

Support by FUI
Objective of the Smart-EEG project

- A system for remote diagnostic
Requirements

- Importance of video signals for medical experts
  - To detect fast movements such as myoclonuses (~20 ms)
  - To measure the delay between cortical events (EEG) and their muscular response (Video and EMG)
- Need to acquire video at 100 frames/second
State of the art

- Physiological and video signals are grabbed by a PC with a non deterministic delay resulting from the OS, etc.

- => Impossibility to synchronize precisely the two streams

- Video @ 25-30 frames/second
LIP6 Objectives in the project

- Design an embedded system for EEG telemedicine capable of
  - Synchronizing precisely physiological signals with video and audio.
  - Acquiring and compressing vidéo stream @ 100 frames/seconde
  - Being certified as a medical device

- Here focus on synchronization
  - PhD of Laurent Lambert
  - Presented at EMBC, August 26, 2015, Milano
Synchronization

- Synchronization at two levels:
  - Hardware synchronization
  - System level synchronization
Multimedia Containers

Reference clock

Multimedia stream

Time

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Which Multimedia Container Format?

- **EDF + MP4**
- **AVI**
- **FLV**
- **ASF**
- **SMIL**
- **MpegX-Systems**
- **MKV**

- Supports compression
- Compactness/Binary
- Agnostic
- Free of use

MKV fulfills our constrains
Proof of Concept: MKV

- Used FFmpeg implementation of MKV
- Added a new type of track in MKV: Physiological
Conclusion and Perspectives

- Conclusion
  - Novel synchronization for multimodal exams
  - Proof of concept using MKV
  - Enhanced features with low overhead

- Perpectives
  - Exploration of Mpeg based solution
  - Coupling with hardware synchronization
  - Evaluation by medical experts
V. Conclusion and perspectives
Conclusions

- Physiological signals acquisition
  - Chronical everyday monitoring of physiological signals for medical diagnostic

- Compression and quality
  - Explosion of health data require lossy compression
  - However compression algorithms have to guarantee diagnostic quality of the reconstructed images

- Telemedicine systems
  - High frequency and precise synchronization between physiological signals, audio and video are needed for diagnostic of difficult cases
  - High-level synchronization allows compression and editing of ≠ modalities
Perspectives

- Link with the SeNSE project of SMART Labex
  - LIP6 case study on affective gaming: emotion recognition of video game players
  - Poster presented by Mrs Wenlu Yang at the COMPOSES School: “Emotion recognition with an embedded system”
  - Several other presentations at COMPOSES related to the SeNSE project

- Long term applications to computational social and behavioral sciences
  - High frequency compressed and synchronized multi-modal acquisition
Thanks

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- Participants to the mentioned projects
Contacts for the projects

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- **Smart-EEG**: Patrick.Garda@upmc.fr
- **SeNSE**: Catherine.Achard@upmc.fr
Publications for SPINALCOM

- With SMART Labex support:

- Before:
Publications for WARM

International Publications


National Publications

Publications for Smart-EEG

- **National Conferences:**

- **International Conferences:**