Digital Signal Processing

Module 10: The End!

Module Overview:

- Module 10.1: Signal processing courses you can take from here
- Module 10.2: Some research projects that use techniques you learned here
- Module 10.3: Examples of start-ups that use signal processing as a core technology
- Module 10.4: Acknowledgements

Digital Signal Processing

Module 10.1: Signal processing courses you can take from here

Overview:

- Statistical Signal Processing
- Signal Processing for Audio and Acoustics
- Mathematical Foundations of Signal Processing
- Advanced Topics in Signal Processing

Overview:

- Statistical Signal Processing
- Signal Processing for Audio and Acoustics
- Mathematical Foundations of Signal Processing
- Advanced Topics in Signal Processing

Overview:

- Statistical Signal Processing
- Signal Processing for Audio and Acoustics
- Mathematical Foundations of Signal Processing
- Advanced Topics in Signal Processing

Overview:

- Statistical Signal Processing
- Signal Processing for Audio and Acoustics
- Mathematical Foundations of Signal Processing
- Advanced Topics in Signal Processing

Statistical Signal and Processing through Applications 1/3

Why do we need statistical tools to process signals?

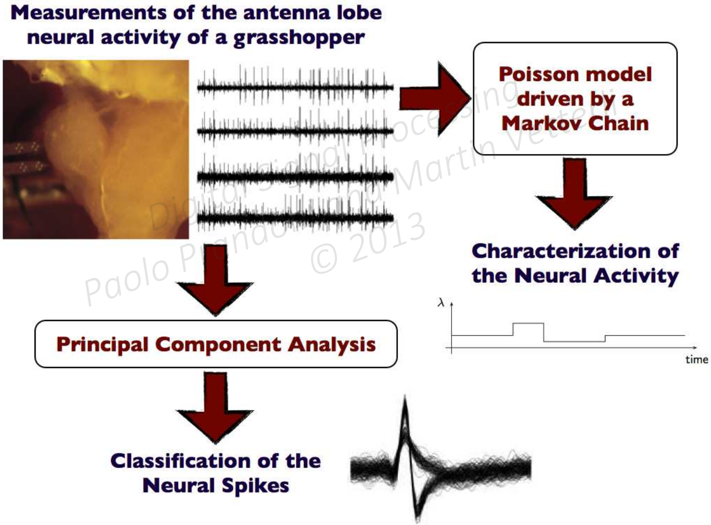
- Real life measurements can often be modelled as a stochastic process, taking into account uncertainties and noise
- Processing methods might have to adapt to changing conditions
- Optimal estimation of specific characteristics of a signal requires specific stochastic models and statistical techniques

What are the problems we want to address?

- Spectral estimation for Wireless Transmissions, Biomedical Signals, Audio Signals
- Classification of Neurobiological Spikes
- Adaptive filtering for echo cancellation in Voice-Over-IP transmissions

Statistical Signal Processing 2/3

An exemplary application:



Statistical Signal Processing 3/3

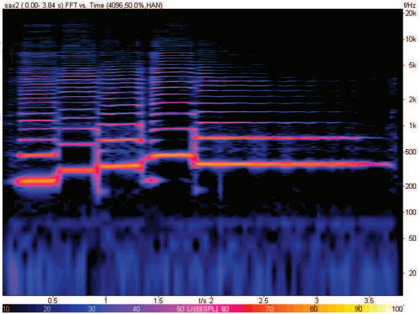
Outline of the class

- Basic models and methods
- Statistical Signal Processing Tools for
  - Wireless Transmissions
  - Echo Cancellation
  - Neurobiological Spikes

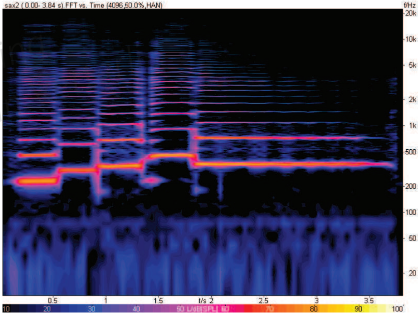
Website of the class

- http://lcav.epfl.ch/teaching/statistical_sp_applications

- The objective of the course is to understand
  - fundamental theories of acoustics and psychoacoustics
  - the process of spatial hearing and spatial audio reproduction
  - the manipulation and processing of audio signals (filtering, delaying and other spectral modifications)
  - state-of-the-art techniques used in pro audio and consumer audio

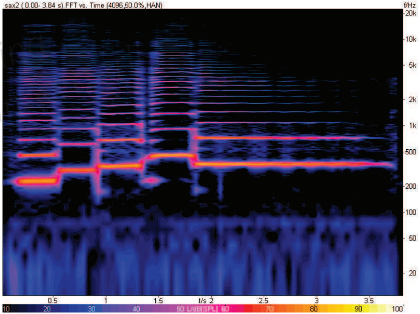


- The objective of the course is to understand
  - fundamental theories of acoustics and psychoacoustics
  - the process of spatial hearing and spatial audio reproduction
  - the manipulation and processing of audio signals (filtering, delaying and other spectral modifications)
  - state-of-the-art techniques used in pro audio and consumer audio

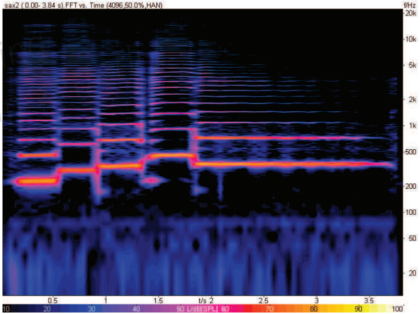


Signal Processing for Audio and Acoustics 1/3

- The objective of the course is to understand
  - fundamental theories of acoustics and psychoacoustics
  - the process of spatial hearing and spatial audio reproduction
  - the manipulation and processing of audio signals (filtering, delaying and other spectral modifications)
  - state-of-the-art techniques used in pro audio and consumer audio

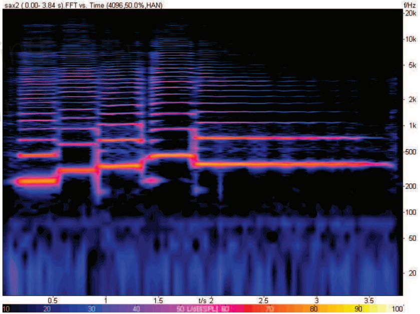


- The objective of the course is to understand
  - fundamental theories of acoustics and psychoacoustics
  - the process of spatial hearing and spatial audio reproduction
  - the manipulation and processing of audio signals (filtering, delaying and other spectral modifications)
  - state-of-the-art techniques used in pro audio and consumer audio

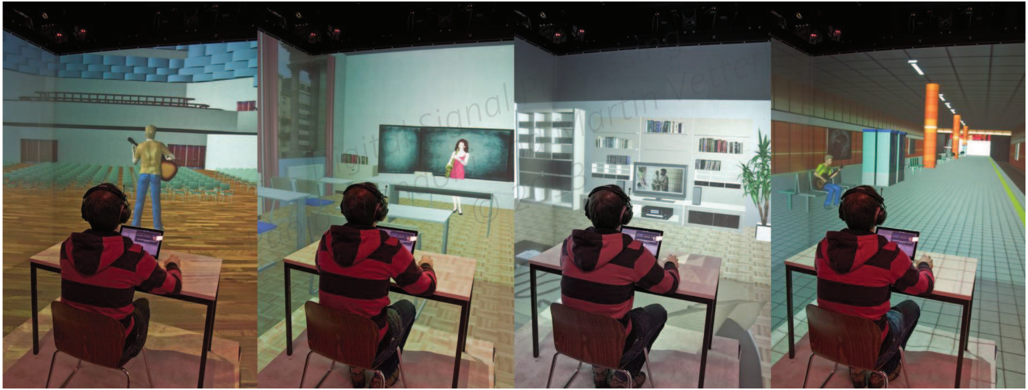


Signal Processing for Audio and Acoustics 1/3

- The objective of the course is to understand
  - fundamental theories of acoustics and psychoacoustics
  - the process of spatial hearing and spatial audio reproduction
  - the manipulation and processing of audio signals (filtering, delaying and other spectral modifications)
  - state-of-the-art techniques used in pro audio and consumer audio

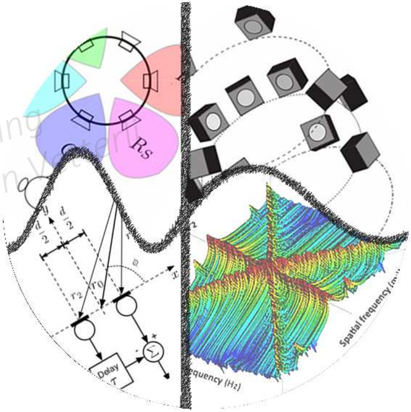


- Auralization - rendering audible (imaginary) sound fields



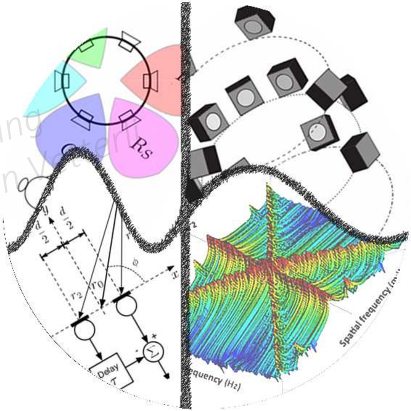
Signal Processing for Audio and Acoustics 3/3

- **Outline of the class**
  - Basics of Spatial Hearing
  - Audio Recording
  - Multichannel Audio Reproduction
  - Spatial Filtering
  - Coding of Audio Signals
  - Auralization



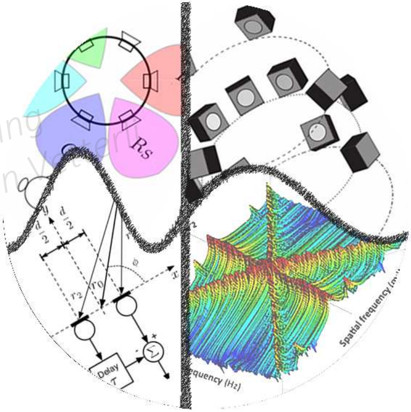
- Details on course website
  http://lcav.epfl.ch/teaching/sp_for_audio_and_acoustics

- Outline of the class
  - Basics of Spatial Hearing
  - Audio Recording
  - Multichannel Audio Reproduction
  - Spatial Filtering
  - Coding of Audio Signals
  - Auralization



- Details on course website
  `http://lcav.epfl.ch/teaching/sp_for_audio_and_acoustics`

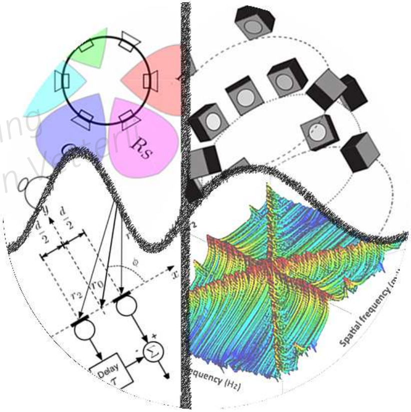
- Outline of the class
  - Basics of Spatial Hearing
  - Audio Recording
  - Multichannel Audio Reproduction
  - Spatial Filtering
  - Coding of Audio Signals
  - Auralization



- Details on course website
  http://lcav.epfl.ch/teaching/sp_for_audio_and_acoustics

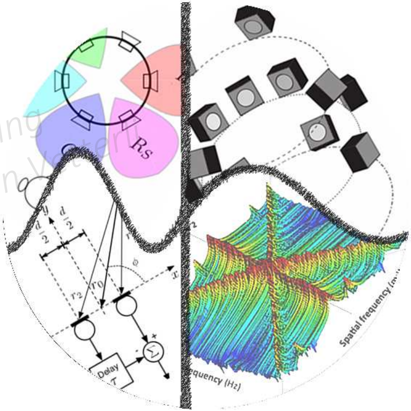
Signal Processing for Audio and Acoustics 3/3

- Outline of the class
  - Basics of Spatial Hearing
  - Audio Recording
  - Multichannel Audio Reproduction
  - Spatial Filtering
  - Coding of Audio Signals
  - Auralization



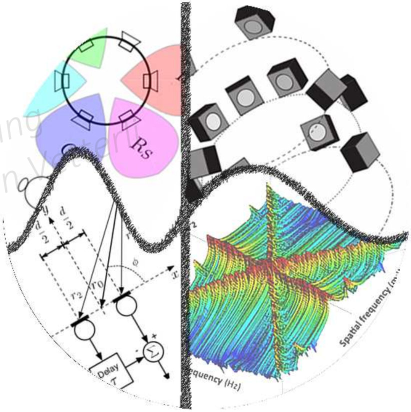
- Details on course website
  `http://lcav.epfl.ch/teaching/sp_for_audio_and_acoustics`

- Outline of the class
  - Basics of Spatial Hearing
  - Audio Recording
  - Multichannel Audio Reproduction
  - Spatial Filtering
  - Coding of Audio Signals
  - Auralization



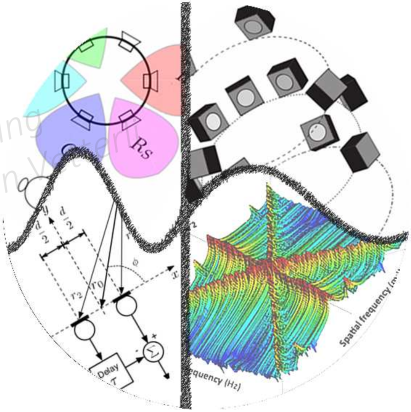
- Details on course website
  http://lcav.epfl.ch/teaching/sp_for_audio_and_acoustics

- Outline of the class
  - Basics of Spatial Hearing
  - Audio Recording
  - Multichannel Audio Reproduction
  - Spatial Filtering
  - Coding of Audio Signals
  - Auralization



- Details on course website
  http://lcav.epfl.ch/teaching/sp_for_audio_and_acoustics

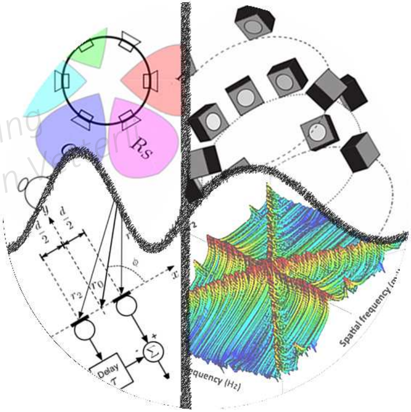
- Outline of the class
  - Basics of Spatial Hearing
  - Audio Recording
  - Multichannel Audio Reproduction
  - Spatial Filtering
  - Coding of Audio Signals
  - Auralization



- Details on course website
  http://lcav.epfl.ch/teaching/sp_for_audio_and_acoustics

Signal Processing for Audio and Acoustics 3/3

- Outline of the class
  - Basics of Spatial Hearing
  - Audio Recording
  - Multichannel Audio Reproduction
  - Spatial Filtering
  - Coding of Audio Signals
  - Auralization



- Details on course website
  `http://lcav.epfl.ch/teaching/sp_for_audio_and_acoustics`

Mathematical Foundations of Signal Processing

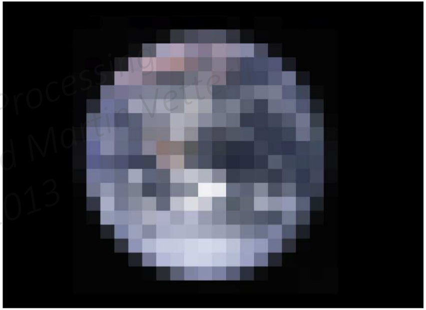
- The world is analog but computation is digital
- How to go between these representations?

$$\text{Analog World} \longrightarrow \boxed{\text{Processing}} \longrightarrow \text{Analog World}$$

Ex: Audio, sensing, imaging, computer graphics, simulations etc

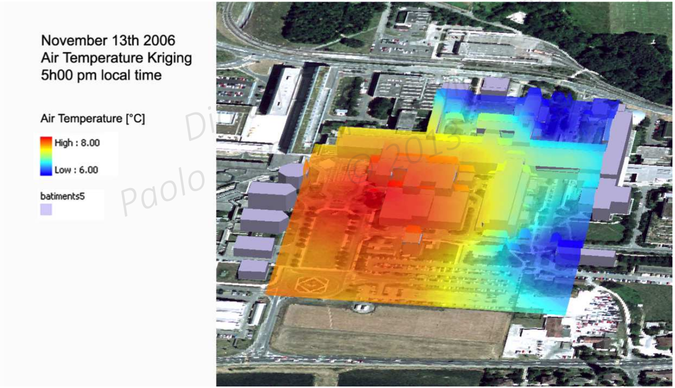
- Key mathematical concepts:
  - Sampling and interpolation
  - Approximation and compression

From Analog to Digital



Example: sensor networks for environmental monitoring

- How many sensors?
- How to reconstruct?



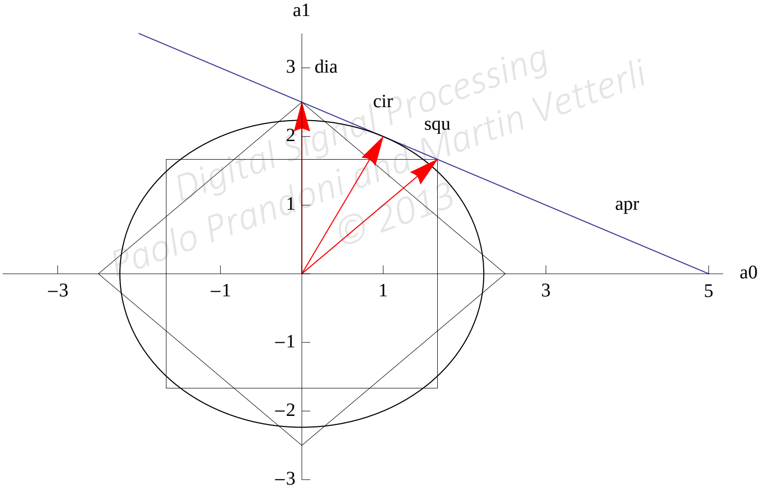
Course Outline

- Brief outline:
  1. From Euclid to Hilbert
  2. Sequences and Discrete-Time Systems
  3. Functions and Continuous-Time Systems
  4. Sampling, Interpolation and Approximation
  5. Applications
- Details on course website
  `http://lcav.epfl.ch/SP_Foundations`
  `http://moodle.epfl.ch/course/view.php?id=13431`
- Textbook: M. Vetterli, J. Kovacevic and V. Goyal, "Foundations of Signal Processing", Cambridge U. Press, 2013. Available in open access at
  `http://www.fourierandwavelets.org`

Advanced Topics in Signal Processing 1/3

- Models and methods used for describing and processing signals arising from physical phenomena constantly increase in complexity
- Classical approaches are not sufficient anymore, since they either cannot be applied, or they lead to wrong results or to labyrinthian computations
- Advanced tools are required to optimally model and analyse the data

Compressed Sensing Example: Expansion with respect to an overcomplete set of vectors is not unique. One can optimize various norms (l_1, l_2, l_∞)



Advanced Topics in Signal Processing 3/3

The course proposes every year one of the following topics

- Fourier and wavelets signal processing
- Mathematical principles of signal processing
- Selected current topics in signal processing
  (sparse signal processing, signal processing for sensor networks, etc.)

Website and textbook of the class

- http://lcav.epfl.ch/teaching/advanced_sp
- Volume 2 of http://www.fourierandwavelets.org

END OF MODULE 10.1

Digital Signal Processing

Module 10.2: Some research projects that use techniques you learned here

Overview:

- eFacsimile or art work acquisition, representation and rendering
- Signal processing for sensors networks
- Source localization in graphs
- Finite rate of innovation sampling
- Sampling of fields
- Image acquisition using oversampled binary pixels
- Predicting the stock market
- Inversion of the diffusion equation
- The Fukushima inverse problem
- Can you hear the shape of a room

Overview:

- eFacsimile or art work acquisition, representation and rendering
- Signal processing for sensors networks
- Source localization in graphs
- Finite rate of innovation sampling
- Sampling of fields
- Image acquisition using oversampled binary pixels
- Predicting the stock market
- Inversion of the diffusion equation
- The Fukushima inverse problem
- Can you hear the shape of a room

Overview:

- eFacsimile or art work acquisition, representation and rendering
- Signal processing for sensors networks
- Source localization in graphs
- Finite rate of innovation sampling
- Sampling of fields
- Image acquisition using oversampled binary pixels
- Predicting the stock market
- Inversion of the diffusion equation
- The Fukushima inverse problem
- Can you hear the shape of a room

Overview:

- eFacsimile or art work acquisition, representation and rendering
- Signal processing for sensors networks
- Source localization in graphs
- Finite rate of innovation sampling
- Sampling of fields
- Image acquisition using oversampled binary pixels
- Predicting the stock market
- Inversion of the diffusion equation
- The Fukushima inverse problem
- Can you hear the shape of a room

Overview:

- eFacsimile or art work acquisition, representation and rendering
- Signal processing for sensors networks
- Source localization in graphs
- Finite rate of innovation sampling
- Sampling of fields
- Image acquisition using oversampled binary pixels
- Predicting the stock market
- Inversion of the diffusion equation
- The Fukushima inverse problem
- Can you hear the shape of a room

Overview:

- eFacsimile or art work acquisition, representation and rendering
- Signal processing for sensors networks
- Source localization in graphs
- Finite rate of innovation sampling
- Sampling of fields
- Image acquisition using oversampled binary pixels
- Predicting the stock market
- Inversion of the diffusion equation
- The Fukushima inverse problem
- Can you hear the shape of a room

Overview:

- eFacsimile or art work acquisition, representation and rendering
- Signal processing for sensors networks
- Source localization in graphs
- Finite rate of innovation sampling
- Sampling of fields
- Image acquisition using oversampled binary pixels
- Predicting the stock market
- Inversion of the diffusion equation
- The Fukushima inverse problem
- Can you hear the shape of a room

Overview:

- eFacsimile or art work acquisition, representation and rendering
- Signal processing for sensors networks
- Source localization in graphs
- Finite rate of innovation sampling
- Sampling of fields
- Image acquisition using oversampled binary pixels
- Predicting the stock market
- Inversion of the diffusion equation
- The Fukushima inverse problem
- Can you hear the shape of a room

Overview:

- eFacsimile or art work acquisition, representation and rendering
- Signal processing for sensors networks
- Source localization in graphs
- Finite rate of innovation sampling
- Sampling of fields
- Image acquisition using oversampled binary pixels
- Predicting the stock market
- Inversion of the diffusion equation
- The Fukushima inverse problem
- Can you hear the shape of a room

Overview:

- eFacsimile or art work acquisition, representation and rendering
- Signal processing for sensors networks
- Source localization in graphs
- Finite rate of innovation sampling
- Sampling of fields
- Image acquisition using oversampled binary pixels
- Predicting the stock market
- Inversion of the diffusion equation
- The Fukushima inverse problem
- Can you hear the shape of a room

eFacsimile 1/3

People involved:

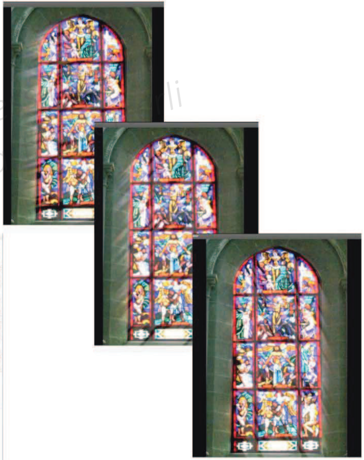
- Joint project between LCAV and Google Inc.
- Dr. Loïc Baboulaz
- Ms. Mitra Fatemi
- Mr. Niranjan Thanikachalam
- Mr. Zhou Xue

What are the problems addressed?

- How to capture, represent and render an Artwork faithfully?
- How to achieve relighting, 3D manipulation and high-resolution on mobile devices?

eFacsimile 2/3

Demo: interactive relighting and manipulation of Oil Paintings and Stained Glasses



What tools used?

- Traditional and light-field cameras
- Light transport theory
- Sparse recovery methods

Websites

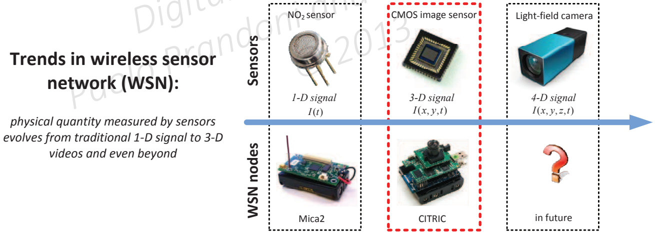
- http://lcav.epfl.ch/cms/site/lcav/lang/en/efacsimile
- http://www.youtube.com/user/lcavepfl

People involved:

- Zichong Chen, Guillermo Barrenetxea, Martin Vetterli

Video monitoring with autonomous wireless camera nodes. Challenges include:

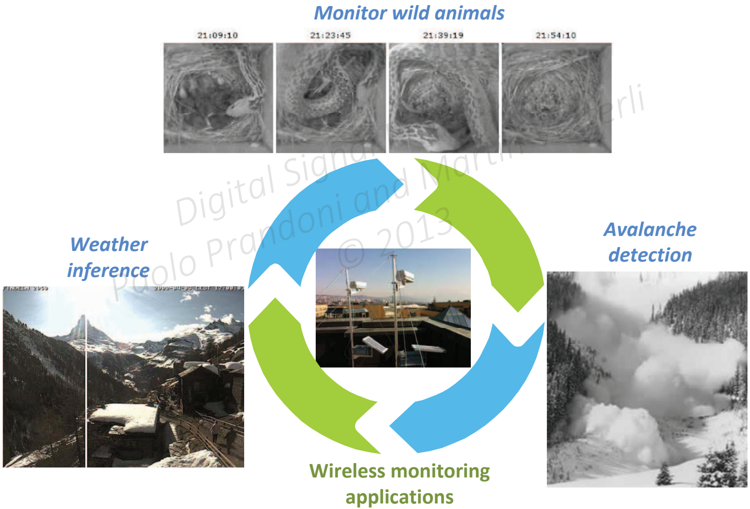
- Each node has very limited energy (e.g., 100 mW from solar panel)
- Need to capture, process and transmit 3-D signals (e.g., 900 kilobytes per image), which requires far more energy than the budget



Tools for better representing and understanding image signals: **image compression** (low level), **computer vision** (high level)

Visual Monitoring using Wireless Sensor Networks

- Many real-world applications by using wireless cameras



Results so far

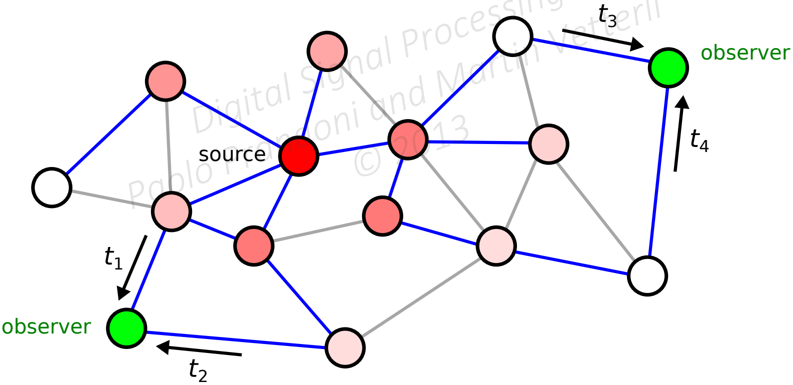
- N cameras can collaboratively share the monitoring task and reduce energy per node by a factor of N
- Understanding video content via computer vision techniques improves video compression efficiency by 70% over conventional H.264 codec

Further references

- Thesis on Cooperative Visual Monitoring in Energy-Constrained Wireless Sensor Networks: `http://infoscience.epfl.ch/record/183072`
- Supported by the grant from NCCR-MICS, `http://www.mics.org`

People involved: Dr Pedro Pinto, Prof Patrick Thiran

- Goal: Locate the source of diffusion in a network with thousands of nodes
- Challenges: Observer are sparsely-placed, have only time-of-arrivals



Source localization

Our contributions:

- Developed optimal and efficient algorithms that exploit time-of-arrivals.
- Achieve 90% accuracy with typically less than 20% observers.

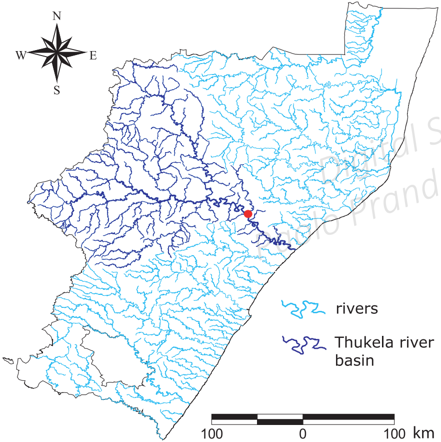
Future directions:

- Optimal placement of observers.
- Disease control and public health.
- Social media analytics.

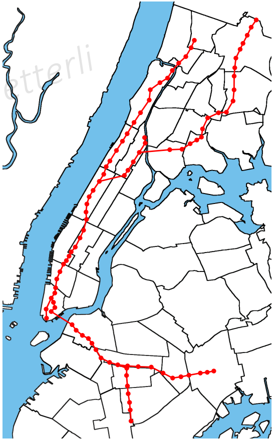
- "Locating the Source of Diffusion in Large-Scale Networks", P. Pinto, P. Thiran, M. Vetterli, Physical Review Letters, Aug. 2012.
- Project funded by the Bill and Melinda Gates Foundation.

Applications

- Cholera outbreak in the KwaZulu-Natal province, South Africa, 2001



- Airborne contamination of transportation infrastructure (NYC subway)



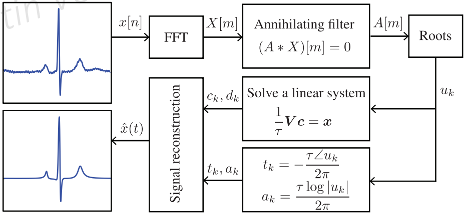
Finite Rate of Innovation (FRI)

People involved:

- Dr. Nikolaos Freris, Senior Scientist
- Gilles Baechler, Doctoral Assistant
- Ehsaneddin Asgari, M.Sc. Assistant
- Orhan Öçal, M.Sc. Assistant

What is FRI?

- Sampling and reconstruction of signals with a finite number of parameters (per unit of time)
- Typical signals: periodic streams of Dirac pulses, periodic non-uniform splines



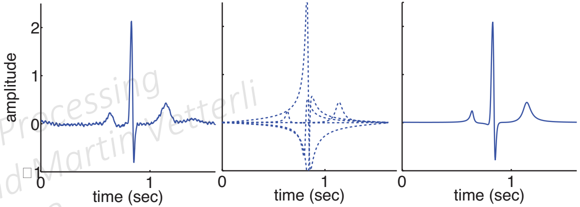
DSP Tools

- Fast Fourier Transform
- Singular Value Decomposition
- Annihilating filter (root finding for complex exponentials)

ECG Modeling

Variable Pulse Width (VPW)

- Extension of FRI to a wider range of waveforms
- Model signals as a sum of asymmetric pulses



Industrial Collaborator

QUALCOMM®

Advantages

- Compression
- Noise removal

Publications

- M. Vetterli, P. Marziliano, and T. Blu. Sampling Signals With Finite Rate of Innovation. IEEE Transactions on Signal Processing, vol. 50, no. 6, June 2002.
- G. Baechler, N. Freris, R.F.Quick, and R.E. Crochiere. Finite rate of innovation based modeling and compression of ECG signals. ICASSP 2013.
- Hormati, A., Vetterli, M., Compressive Sampling of Multiple Sparse Signals Having Common Support Using Finite Rate of Innovation Principles, Signal Processing Letters, IEEE, vol.18, no.5, pp.331,334, May 2011.
- Y. Barbotin and M. Vetterli. Fast and Robust Parametric Estimation of Jointly Sparse Channels, in Journal on Emerging and Selected Topics in Circuits and Systems, IEEE, vol. PP, num. 99, p. 1-11, 2012.
- A. Hormati and M. Vetterli. Distributed Compressed Sensing: Sparsity Models and Reconstruction Algorithms Using Annihilating Filter. ICASSP, Las Vegas, Nevada, USA, March 30-April 4, 2008.

Sampling spatial fields using mobile sensors 1/3

People involved:

- Jayakrishnan Unnikrishnan
- Martin Vetterli

Research challenges

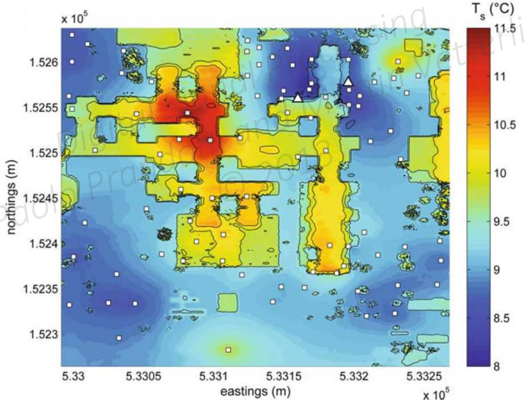
- Algorithms for reconstructing a spatial field using discrete measurements taken by sensors
- Sampling spatial fields with mobile sensors
  - Design of efficient sensor trajectories that minimize the total distance traveled by the sensors
  - Spatial processing via time-domain filtering

Tools used

- Classical sampling theory and Fourier analysis in higher dimensions

Sampling spatial fields using mobile sensors 2/3

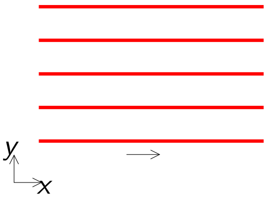
Application: Surface temperature measurement in EPFL campus



Sampling spatial fields using mobile sensors 3/3

Insights from research

- Sampling along equispaced parallel lines (see figure) is optimal over a wide range of configurations of sensor trajectories for 2D low-pass fields
- Spatial anti-aliasing can be induced by using mobile sensors with time-domain filtering



Key papers available at `http://lcav.epfl.ch/people/jayakrishnan.unnikrishnan`

- J. Unnikrishnan and M. Vetterli, "Sampling High-Dimensional Bandlimited Fields on Low-Dimensional Manifolds" accepted for publication in IEEE Transactions on Information Theory, Oct 2012.
- J. Unnikrishnan and M. Vetterli, "Sampling and Reconstruction of Spatial Fields using Mobile Sensors" accepted for publication in IEEE Transactions on Signal Processing, Feb 2013.

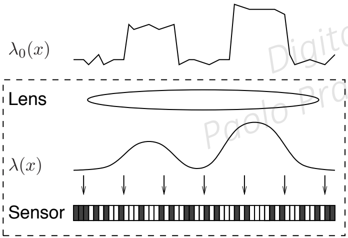
Image acquisition using oversampled binary pixels 1/3

People involved:

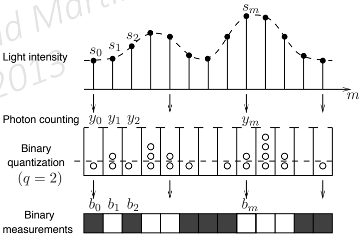
- Feng Yang, Luciano Sbaiz (Google Zürich), Yue M. Lu (Harvard University), Sabine Süsstrunk, Hyungjune Yoon, Edoardo Charbon, Martin Vetterli

What are the problems addressed?

- Propose an image sensor with binary pixels, used for high dynamic range imaging



Imaging model



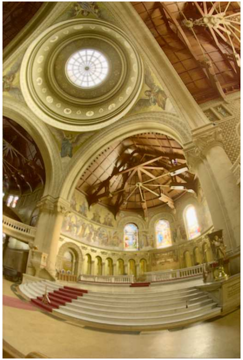
Model of the binary sensor

- Reconstruct the light intensity field from binary measurements

Image acquisition using oversampled binary pixels 2/3

Experimental results

- Synthetic image



Spatial: 64×64
Temporal: 64

- Read sensor data

Single-photon avalanche diode (SPAD) camera

Pixel value: binary
Sensitivity: single photon
Resolution: 32×32
Temporal oversampling to emulate spatial oversampling

Reconstruction from 4096 consecutive frames

Image acquisition using oversampled binary pixels 3/3

Main publications

- Feng Yang, Yue M. Lu, Luciano Sbaiz, and Martin Vetterli. Bits from photons: Oversampled image acquisition using binary Poisson statistics. *IEEE Transactions on Image Processing*, vol. 21, issue 4, pp. 1421-1436, 2012.
- Feng Yang, Martin Vetterli. Oversampled noisy binary image sensor. *Proc. of IEEE Int. Conference on Acoustics, Speech and Signal Processing*, Vancouver, May 26-31, 2013.
- Luciano Sbaiz, Feng Yang, Edoardo Charbon, Sabine Süsstrunk, and Martin Vetterli. The gigavision camera. In *Proc. of IEEE Int. Conference on Acoustics, Speech and Signal Processing*, pp.1093-1096, Taipei, Apr. 2009.

Website and other pointers

- Feng Yang's PhD thesis `http://infoscience.epfl.ch/record/174695?ln=en`
- `http://lcav.epfl.ch/research/gigavision`

Predicting the stock market

People involved:

- Lionel Coulot
- Peter Bossaerts

What are the problems addressed?

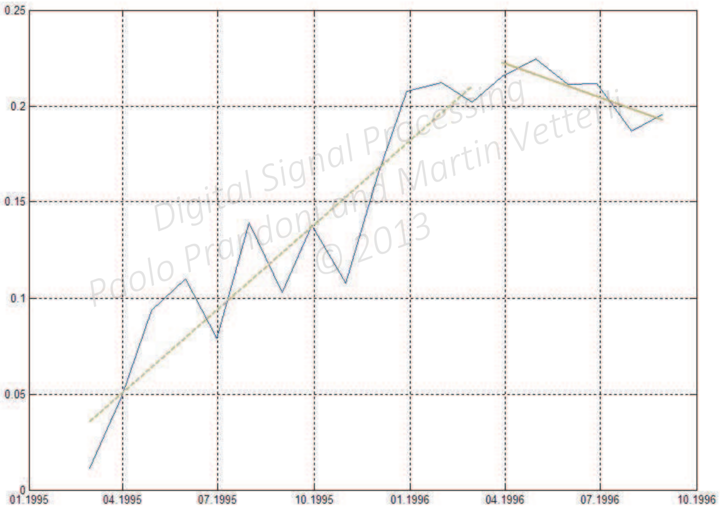
- prediction means identifying features in observed data and extrapolating them in the future in the hope they persist
- features expressed using statistical models that account for the inherent randomness in data
- how do we decide between a simple and a more complex model?
- on which portion of the observed data do we learn the model?

What tools used?

- coding theory
- dynamic programming

Predicting the stock market

An exemplary application: dynamic trend line



Predicting the stock market

Results so far

- project completed

Website and other pointers

- PhD thesis
- `http://infoscience.epfl.ch/record/182936`
- Sponsor
- `http://www.lgt.com`

Inversion of the diffusion equation 1/3

People involved:

- Juri Ranieri, Ivan Dokmanić, Amina Chebira, Yue Lu, Martin Vetterli

What are the problems addressed?

- Model for many physical phenomena: temperature, atmospheric dispersion, ...
- We measure the field at certain locations in space and time
- Target: estimate the sources of the field
- Variations: advective diffusive phenomena, time varying sources, ...

What tools used?

- Fourier analysis, Signals with Finite Rate of Innovation, Compressive Sensing

Inversion of the diffusion equation 2/3

An exemplary application: estimation of time-varying atmospheric emissions

Inversion of the diffusion equation 3/3

What we have shown so far

- Recovery spatially sparse sources appearing at unknown time
- Recovery of time-varying emissions with FRI
- Recovery of the field using traditional sampling technique exploiting the low-pass kernel

Main Publications

- J. Ranieri, Y. Lu, A. Chebira and M. Vetterli. *Sampling and Reconstructing Diffusion Fields with Localized Sources*
- I. Dokmanic, J. Ranieri, A. Chebira and M. Vetterli. *Sensor Networks for Diffusion Fields: Detection of Sources in Space and Time*
- J. Ranieri, I. Dokmanic, A. Chebira and M. Vetterli. *Sampling and Reconstruction of Time-Varying Atmospheric Emissions*
- J. Ranieri and M. Vetterli. *Sampling and reconstructing diffusion fields in presence of aliasing*

The Fukushima Inverse Problem 1/3

People involved:

- Marta Martinez-Camara, Ivan Dokmanic, Juri Ranieri, Robin Scheibler, Martin Vetterli.
- Andreas Stohl, from NILU, Norway.

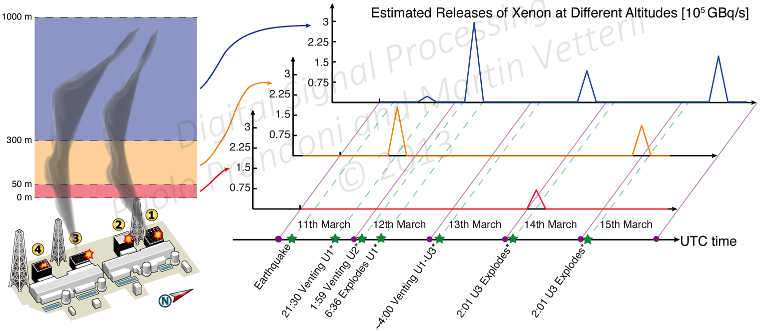
What are the problems addressed?

- We want to estimate the emissions of radionucleides during a nuclear accident.
- Using a few sensors located all around the world.

What tools used?

- Sparse regularizations.
- Atmospheric dispersion models.

An example application: Estimation of Xenon emissions from Fukushima.



The Fukushima Inverse Problem 3/3

Something about the results so far

- We estimated the Xenon emissions from Fukushima without using any a priori information.
- We showed that all the Xenon accumulated in the nuclear power plant before the accident was released in the first 5 days after the earthquake.

Website and other pointers

- `http://infoscience.epfl.ch/record/182697`
- M.Martinez-Camara, I.Dokmanic, J.Ranieri, R.Scheibler, M. Vetterli, A.Stohl, "The Fukushima Inverse Problem," Proc IEEE ICASSP, May 2013.

Can One Hear the Shape of a Room?

- People: Ivan Dokmanić, Reza Parhizkar, Andreas Walther, Martin Vetterli and Yue M. Lu (Harvard School of Engineering)
- Remember 5.12: Dereverberation and Echo Cancelation?
- If you know "room shape", you can get rid of the echoes
- *If* you know the shape... but can we know it?
- *Imagine you're blindfolded inside an unknown room and you snap your fingers. Can you hear the shape of the room?*

Can One Hear the Shape of a Room?

- People: Ivan Dokmanić, Reza Parhizkar, Andreas Walther, Martin Vetterli and Yue M. Lu (Harvard School of Engineering)
- Remember 5.12: Dereverberation and Echo Cancelation?
- If you know "room shape", you can get rid of the echoes
- *If* you know the shape... but can we know it?
- *Imagine you're blindfolded inside an unknown room and you snap your fingers. Can you hear the shape of the room?*

- People: Ivan Dokmanić, Reza Parhizkar, Andreas Walther, Martin Vetterli and Yue M. Lu (Harvard School of Engineering)
- Remember 5.12: Dereverberation and Echo Cancelation?
- If you know "room shape", you can get rid of the echoes
- *If* you know the shape... but can we know it?
- *Imagine you're blindfolded inside an unknown room and you snap your fingers. Can you hear the shape of the room?*

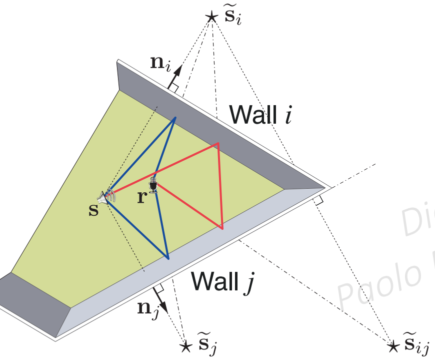
Can One Hear the Shape of a Room?

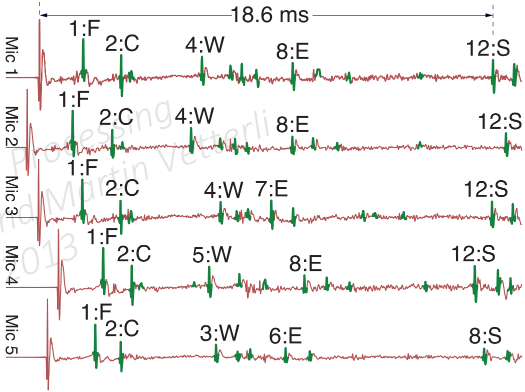
- People: Ivan Dokmanić, Reza Parhizkar, Andreas Walther, Martin Vetterli and Yue M. Lu (Harvard School of Engineering)
- Remember 5.12: Dereverberation and Echo Cancelation?
- If you know "room shape", you can get rid of the echoes
- *If* you know the shape... but can we know it?
- *Imagine you're blindfolded inside an unknown room and you snap your fingers. Can you hear the shape of the room?*

Can One Hear the Shape of a Room?

- People: Ivan Dokmanić, Reza Parhizkar, Andreas Walther, Martin Vetterli and Yue M. Lu (Harvard School of Engineering)
- Remember 5.12: Dereverberation and Echo Cancelation?
- If you know "room shape", you can get rid of the echoes
- *If* you know the shape... but can we know it?
- *Imagine you're blindfolded inside an unknown room and you snap your fingers. Can you hear the shape of the room?*

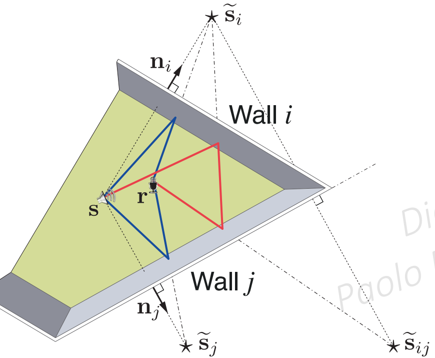
How Does One Hear the Room?

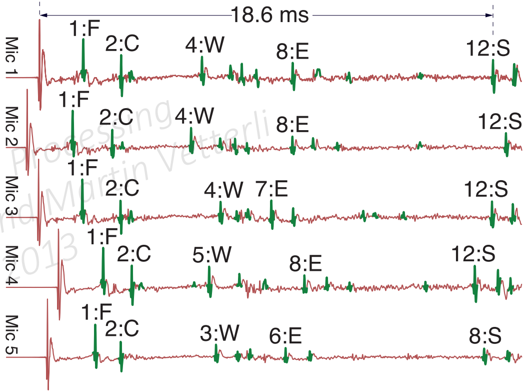




- Aim: Reconstruct the shape of the room from acoustic reponses (as few as possible!)
- How many suffice? We can get a *robust* algorithm with 4!

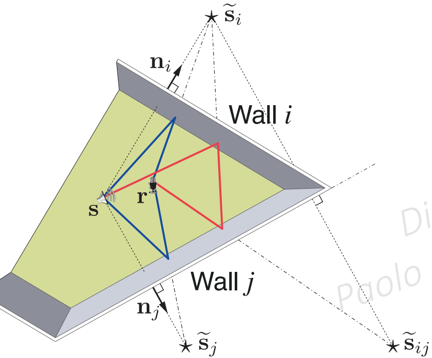
How Does One Hear the Room?

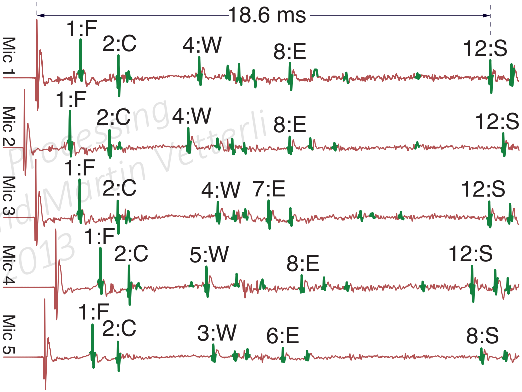




- Aim: Reconstruct the shape of the room from acoustic reponses (as few as possible!)
- How many suffice? We can get a *robust* algorithm with 4!

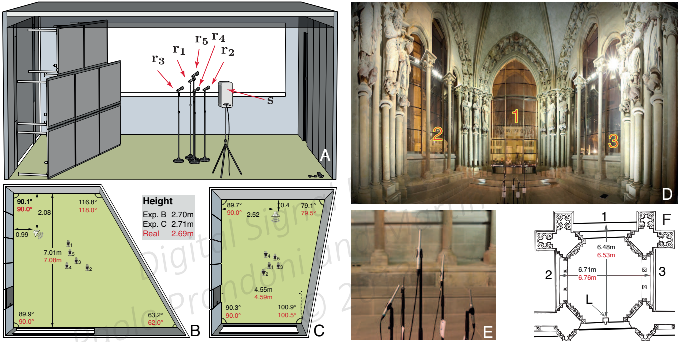
How Does One Hear the Room?



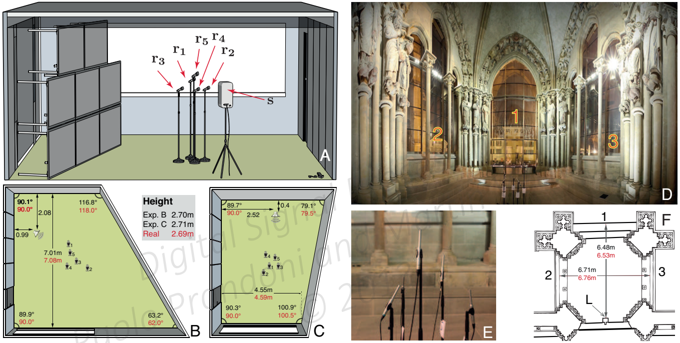


- Aim: Reconstruct the shape of the room from acoustic reponses (as few as possible!)
- How many suffice? We can get a *robust* algorithm with 4!

Yes We Can!

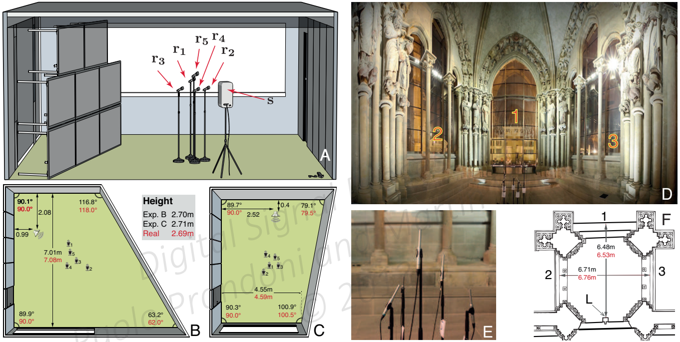


- Exploiting the geometry of echoes we get stunning results
- One *can* hear the shape of a room!
- For more info & publications, visit http://lcav.epfl.ch/people/ivan.dokmanic



- Exploiting the geometry of echoes we get stunning results
- One *can* hear the shape of a room!
- For more info & publications, visit http://lcav.epfl.ch/people/ivan.dokmanic

Yes We Can!



- Exploiting the geometry of echoes we get stunning results
- One *can* hear the shape of a room!
- For more info & publications, visit http://lcav.epfl.ch/people/ivan.dokmanic

END OF MODULE 10.2

Digital Signal Processing

Module 10.3: Examples of start-ups that use signal processing as a core technology

Overview:

- Illusonic
- Quividi
- Sensorscope
- Vidinoti

Overview:

- Illusonic
- Quividi
- Sensorscope
- Vidinoti

Overview:

- Illusonic
- Quividi
- Sensorscope
- Vidinoti

Overview:

- Illusonic
- Quividi
- Sensorscope
- Vidinoti

Illusonic 1/3

What are the problems addressed?

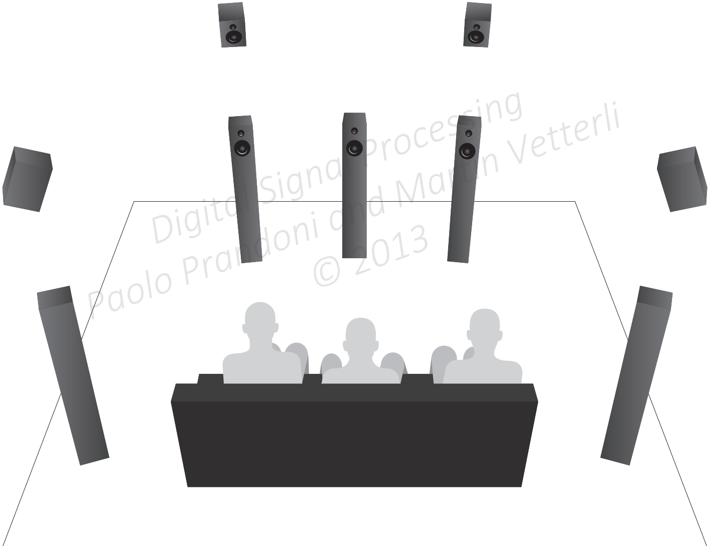
- Acoustic signal processing (beamforming, echo control, soundbar, ...)
- Spatial audio processing (3D audio, upmix, effects, ...)
- Audio engineering tools (de-reverb, de-noise, ...)
- etc

What tools used?

- Digital signal processing (filter design, FFT, re-sampling, ...)
- Acoustic models
- Perceptual models

Illusonic 2/3

An exemplary application: Sound in 3D



Illusonic 3/3

Something about the company

- 5 employees
- Licensable technologies for pro, consumer, voice
- Custom technology adaptation/development
- Immersive Audio Processor

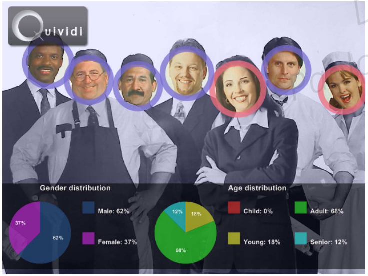
Website and other pointers

- `http://www.illusonic.com`

Quividi: automated audience measurement

Quividi provides qualified audience measurement using video analytics and off-the-shelf hardware:

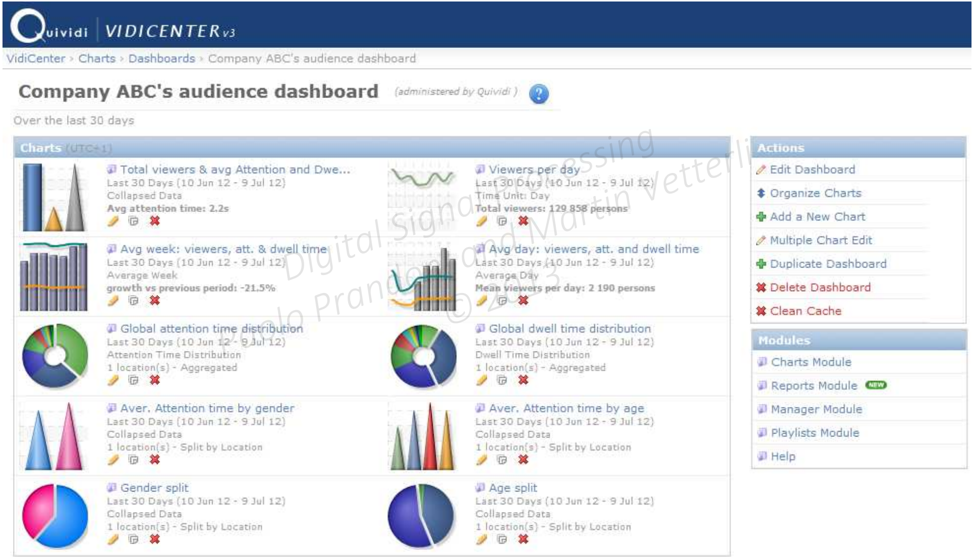
- real-time processing of video streams
- data relayed to main data warehouse
- customers access formatted data remotely



Most metrics based on face detection/analysis:

- number of viewers, attention time, dwell time...
- gender, age estimation...
- footfall count via zenithal cameras

Quividi: audience data dashboards



http://www.quividi.com

Sensorscope

What are the problems addressed?

- Environmental monitoring: real-time spatial visualization
- Precision agriculture: secure, control, and optimize crop production
- Sensor data management: access/control/share data anywhere/anytime

What tools used?

- Wireless sensor networks (WSN)
- Signal and image processing: sampling, compression, reconstruction...
- Radio communication

An exemplary application: environmental monitoring with sensor networks

Sensorscope 3/3

About the company

- 5 employees
- Main markets: environmental monitoring, precision agriculture
- Main product: DS3 system, flexible modules to easily compose a WSN

Website and other pointers

- `http://www.sensorscope.ch`
- `http://www.climaps.com`

Vidinoti 1/3

Vidinoti is active in the field of Augmented Reality on mobile devices. More specifically, the main challenges are:

- Image recognition robust to environment changes (lighting, distortion, ...)
- Time and memory constraints to perform real-time image recognition and tracking on mobile devices
- Load balancing between remote server, containing a large amount of images to recognize, and mobile devices

To tackle these challenges, Vidinoti uses:

- Advanced image recognition algorithms
- Objects tracking taking advantage of sensors and image data
- Algorithm optimization tailored to mobile devices

Vidinoti 2/3

Vidinoti technology is cloud-based, providing a seamless integration of all Augmented Reality components to customers.

Vidinoti 3/3

Vidinoti started in 2010 as a spin-off of the LCAV, now in Fribourg (CH).
The company currently employs about 10 people having the missions of:

- Business development
- Research and development
- IP watch, investigation and creation

Vidinoti objective is to allow customers to deliver additional multimedia content to their end-users using Augmented Reality, in markets such as:

- Marketing, Printed media, Museums

For more information, please visit Vidinoti website and try the iPhone app, PixLive, using Vidinoti technology:

- `http://www.vidinoti.com`
- `http://www.pixlive.info`

END OF MODULE 10.3

Digital Signal Processing

Module 10.4: Acknowledgements

Acknowledgements

Operations:

- Pedro Pinto
- Juri Ranieri

Recording and editing:

- Jeremy Rieder
- Tao Lee

Content reviewers:

- Jay Unnikrishnan
- Youssef El Baba
- Taher Nguira
- Solene Buet

Numerical examples:

- Andrea Ridolfi
- Lionel Coulot

Acknowledgements

Homework Sets:

- Juri Ranieri
- Yann Barbotin
- Ivan Dokmanic
- Zhou Xue
- Reza Parhizkar
- Feng Yang
- Mihailo Kolundzija
- Mitra Fatemi
- Dirk Schroder
- Andreas Walther
- Alireza Ghasemi
- Marta Martinez-Camara
- Zichong Chen

Acknowledgements

Administration:

- Jacqueline Aeberhard

Funding:

- EPFL

END OF MODULE 10.4

END OF MODULE 10