Audiovisual Communications Laboratory

by Martin Vetterli

A small introduction

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Outline

• Who we are
• Teaching
• Research
  – Mathematical signal processing
  – Inverse problems
  – Plenoptic imaging
  – Digital acoustics
• Tech Transfer
• Graduates of the lab
Who we are...

Martin Vetterli
Jacqueline Aeberhard Administrator

Post-doc Researchers
Loïc Baboulaz
Yun Bai
Benjamin Bejar
Christof Faller
Nikolaos Freris
Mihailo Kolundzija
Paolo Prandoni
Dirk Schröder
Jayakrishnan Unnikrishnan

PhD Students
Juri Ranieri
Ivan Dokmanic
Mitra Fatemi
Alireza Ghasemi
Farid Naini (ca)
Zhou Xue
Runwei Zhang

Engineers
Danil Korchagin
Julien Lalande

Marta Martinez Camara
Robin Scheibler
Niranjan Thanikachalam
Tao Lee
Hanjie Pan
What we teach ...

<table>
<thead>
<tr>
<th>Level</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>BS</td>
<td>Signal Processing For Communications</td>
</tr>
<tr>
<td></td>
<td>Mathematical Foundations of Signal Processing</td>
</tr>
<tr>
<td>MS</td>
<td>Statistical Signal and Data Processing through Applications</td>
</tr>
<tr>
<td></td>
<td>Signal Processing for Audio</td>
</tr>
<tr>
<td>PhD</td>
<td>Advanced Topics in Signal Processing</td>
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</table>
...also via Coursera
What we teach . . .

Textbooks:

![Wavelets and Subband Coding](image1)

![Communications and Information Sciences](image2)

![Foundations of Signal Processing](image3)

![Fourier and Wavelet Signal Processing](image4)

Tutorials and reviews:
Research: Mathematical Signal Processing
From Analog to Digital
Sampling sparse signals

Real world signals are often sparse:

- Molecules
- Room impulse response
- Stars

Sampling, sampling kernel, sampling noise:
Interpolation Vs Parametric

Interpolation:
- Classic approach
- Simple and fast
- Loss of information
- Loss of structure

Parametric recovery (FRI):
- Polynomial complexity
- Minimal amount of samples
- Exact recovery of the information
- Structure preserved
Research: Inverse problems
Inverse Problems in Room Acoustics
Euclid meets Echoes

Can One Hear the Shape of a Room?

Localize Sources & Microphones

Completely Blind Calibration

Echolocation Insights
Inverse Problems in Room Acoustics

Euclid meets Echoes

Image source model  Euclidean distance geometry  Room impulse responses

Echo sorting
Process of putting echoes into space—lifting them from events in 1D room impulse responses to (3+1)D space and time.
Inverse Problems in Room Acoustics

Euclid meets Echoes

[1] One can hear the shape of a room

[2, 3] One can localize using a single sensor (and in non-convex rooms)

[4] One can calibrate many microphones in a fingersnap

Estimating emissions to the atmosphere

• When a substance is emitted to the atmosphere, it spreads in a few days all over the world.

• The Fukushima accident, volcano eruptions or greenhouse gases emissions are some examples.

• Lagrangian Dispersion Models can model how all these substances are dispersed. But they need as an input, among other things, how much material was released, when and where.

• Usually, this is unknown.
A linear inverse problem

\[ y(\xi, t) = \int_0^t A(\xi, \tau)x(\tau)\,d\tau \]

Measurements  \rightarrow  Weather  \rightarrow  Emissions

\[ y = Ax \]

Known  \rightarrow  Estimated  \rightarrow  Unknown
Two cases

Controlled experiment: ETEX

‘Uncontrolled’ experiment: Fukushima
Research: The e-facsimile project
The 4D light field

“Amount of light traveling along all rays in free space”
Light field acquisition

Image sensor  Micro-lens array (mla)

Aperture  Main lens  Scene

Optical axis  Focal plane

LCAV

Lytro

Raytrix
Light-field processing

\[
\frac{1}{\alpha^2 F^2} A_2 \circ B_\alpha[L]
\]

Shear + Integral projection

Image focused on “alpha” plane

Images from Lytro (by L.Baboulaz)
eFacsimile

• How to faithfully represent an artwork on digital devices?

• Image-based approach focusing on:

1. Acquisition:
   • Controlled vs. uncontrolled environment
   • Active vs. passive illumination
   • Digital camera – multispectral camera – light field camera

2. Representation
   • Data compression (sparsity, low rank)
   • Reflectance modeling

3. Rendering
   • Mobile platform / web programming
   • Resolution and interactivity

“17 Ladies with Ermines”, Leonardo Da Vinci

Image by F. Viegas & M. Wattenberg
eFacsimile: web app viewer for paintings

Light dome

Relighting

Zooming & panning

3D brush strokes
eFacsimile: relighting of stained glass

- Recovery of sub-surface scattering and impurities in non-homogeneous translucent materials.
- Micro vs. macro structures
- Uncontrolled environment

Rose window, Cathedral of Lausanne

Relighting with complex illumination

Zoom
Research: Digital acoustics
Physically Based Sound Field Rendering

Building Acoustics Simulation

Directional Patterns of Sound Sources

Flexible Spatial Data Structures

Binaural Rendering

Specular and Diffuse Reflections

Higher Order Diffraction
Interactive Real-time Auralization

The auralization framework lets you experience the acoustics of an interactive environment in an immersive way by rendering true 3D audio at interactive rates.

Enclosures are analyzed in real-time by state-of-the-art room acoustics simulation algorithms to determine the accurate directions on which sound travels through space.
I.AM
(Immersive Archives of Montreux Jazz)

Montreux Jazz Archive

Choose Concert Venue

Immersive Simulation

The MJ Archive comprises over 5,000 hours of video and audio recordings from more than 4,000 concerts.

The archive had lately been given UNESCO heritage status.

Realistically responding virtual 3D-environment for playing back the archives of MJ.

Choose, experience, explore and interact with the virtual venue and musicians!

Web: lcav.epfl.ch/iam
I.AM – The Past
(Immersive Archives of Montreux Jazz)

In 1971, the legendary Montreux Casino burnt down during a concert by Frank Zappa and the Mothers of Invention.

This historic place will be virtually resurrected by reconstructing the Casino’s concert venue from partly existing architectural plans, photos, videos, live recordings and information from contemporary witnesses.
I.AM – The Future
(Immersive Archives of Montreux Jazz)

A new building will be constructed at EPFL to welcome the Montreux Jazz Lab, a social place where people can have a drink, explore the archives, enjoy live concerts and experiences brand new technologies around music, acoustics and multimedia.

We already took a first listen!
PhD students
Graduates and the age factor
Graduates

Michael C. Gastpar
Professor
School of Computer and Communication Sciences
Ecole Polytechnique Federale (EPFL), Lausanne, Switzerland
Adjunct Associate Professor
Department of Electrical Engineering and Computer Sciences
University of California at Berkeley

Jelena Kovačević
Jelena Kovačević is currently an Assistant Professor in the Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign. She received the B.S. and M.S. degrees respectively, from Columbia University.

Kannan Ramchandran
Professor
Research Areas
Communications & Networking (COMNET)
Signal Processing (SP)
Research Centers
Berkeley Audio-visual Signal processing and Communication Systems (BASICS)
Berkeley Wireless Research Center (BWRC)
Connectivity Lab
Wireless Foundations

Vivek Goyal
Assistant Professor
PhD, University of California, Berkeley, 1998

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Associate Professor
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1308 W. Main St.
Urbana, Illinois 61801
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mmndo@illinois.edu
Primary Research Area
Signal Processing

4/15/2014
Some start-ups related to the lab

- **Dartfish**
  - Video special effects
- **Quividi**
  - Audience measurement
- **Illusonic**
  - Spatial audio
- **Sensorscope**
  - Wireless sensor networks
- **Healthsprint**
  - E-Health
- **Vidinoti**
  - Augmented reality
- **Sonoview Acoustic Sensing Technologies**
  - Ultrasound tomography
Start-ups
Some start-ups from graduates
## Tech transfer and patents

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<tr>
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<td><strong>Patent Application Publication</strong></td>
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<td><strong>Pub. Date: Jun. 21, 2007</strong></td>
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<tr>
<td>(19) <strong>Title:</strong> Sampling method, reconstruction method, and device for sampling and/or reconstructing signals</td>
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<td>(54) <strong>Abstract:</strong> Reconstruction method for reconstructing a first signal $x(t)$ regularly sampled at a sub-Nyquist rate, comprising the step of retrieving from the regularly spaced sampled values $x[nT]$, a set of weights $(c_0, c_1, \ldots, c_{N-1})$ and shifts $(d_0, d_1, \ldots, d_{N-1})$ with which said first signal $x(t)$ can be reconstructed. The reconstructed signal $x(t)$ can be represented as a sequence of known functions $y(t)$ weighted by the weights $(c_0, c_1, \ldots, c_{N-1})$ and shifted by the shifts $(d_0, d_1, \ldots, d_{N-1})$. The sampling rate is at least equal to the rate of innovation $(p)$ of the first signal $x(t)$.</td>
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![Diagram](image_url)

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**40 patents**
Thank you for your attention!

Any questions?