Biomedical Informatics and Systems Modeling Graduate Research Expo

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Background & Experience

Major: Biomedical signal processing

Interests: Theories, models, algorithms and devices for vital sign monitoring and analysis

My career:

- Associate Professor of Biomedical Engineering, Shiraz University, **2008-2018**
- Invited Researcher, Grenoble Images Speech Signal and Control Lab (GIPSA-lab), **2018-2020**
- Associate Professor of Emory University Department of Biomedical Informatics, **Since July 2020**

Further information: www.sameni.info

My Active Projects

1. Adult and fetal cardiography
2. Low-cost portable vital sign monitors
3. Blind and semi-blind source separation algorithms
4. Multimodal data fusion
5. Mathematical modeling of the pandemic propagation

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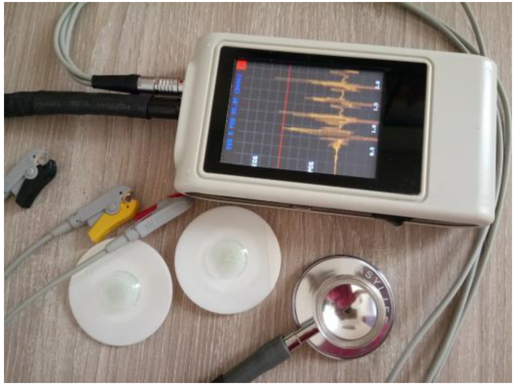
Noninvasive Fetal Electrocardiography

Noninvasive fetal cardiography

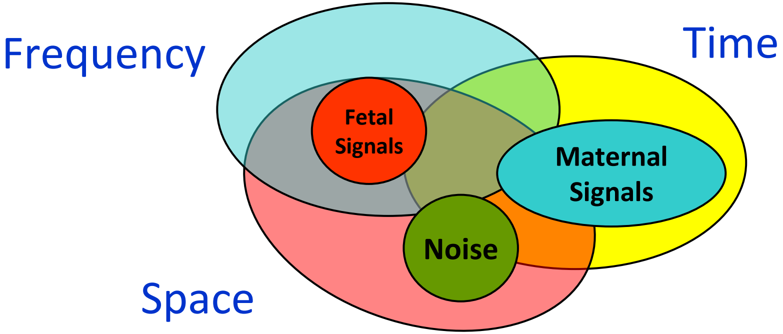
Objective: Noninvasive extraction of fetal electric, acoustic, or magnetic cardiac activities from a set of sensors (electrodes, antenas, stethoscopes) placed on the maternal abdomen

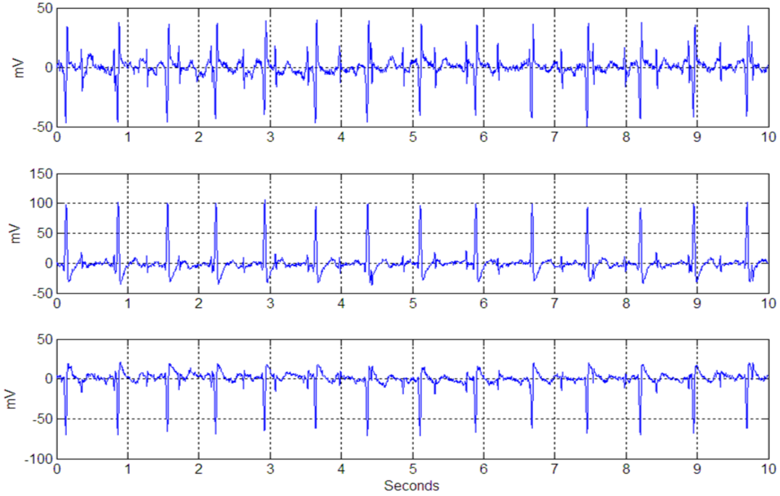


Noninvasive fetal cardiography

Challenges:

- Weakness of the fetal cardiac signals and low conductivity layers
- Strong interferences and noise
- Fetal movements
- Multiple pregnancies (twins, triplets, ...)

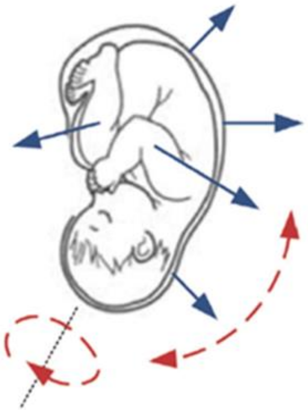


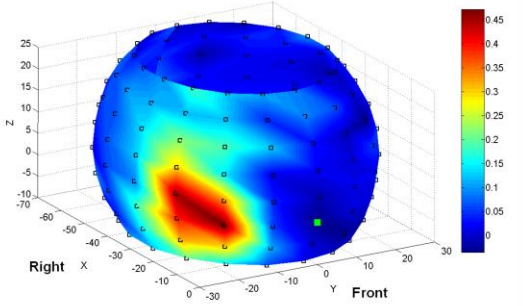


Noninvasive fetal cardiography

Current Research:

- Advanced semi-blind source separation algorithms for fetal ECG/PCG extraction
- Fetal motion and position tracking
- Robust tracking of abnormal and extreme fetal heart rate variations (accelerations/decelerations)

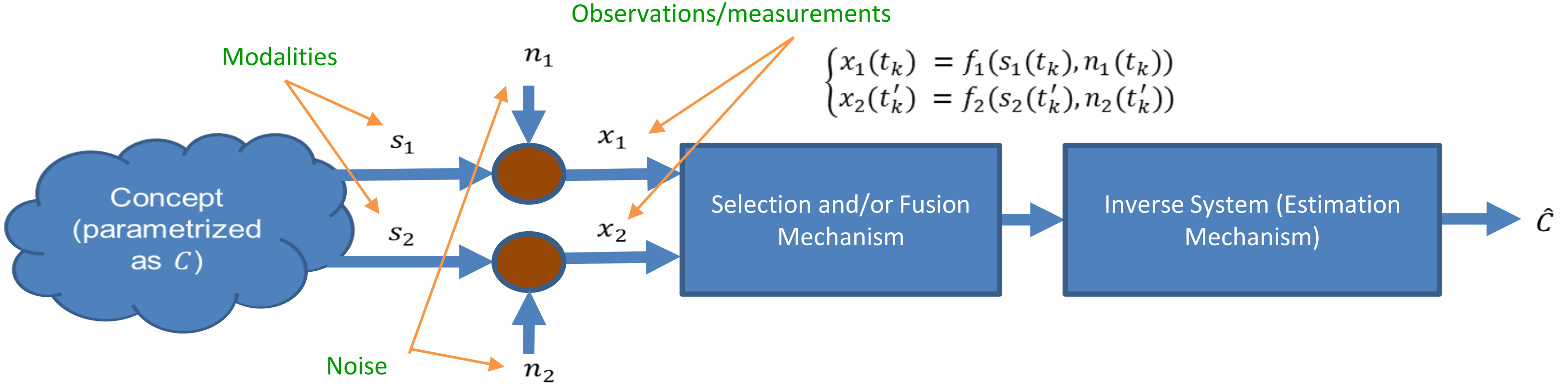




Multimodal Data Fusion

Multimodal Data Fusion

- **Multimodality:** When a concept is observed/monitored through different modalities (measurement systems).
- Each modality covers certain aspects of the concept, at some level of abstraction
- Different modalities may partially overlap with and complement one another

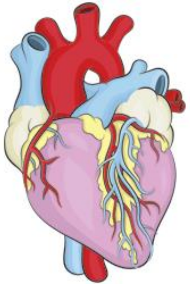


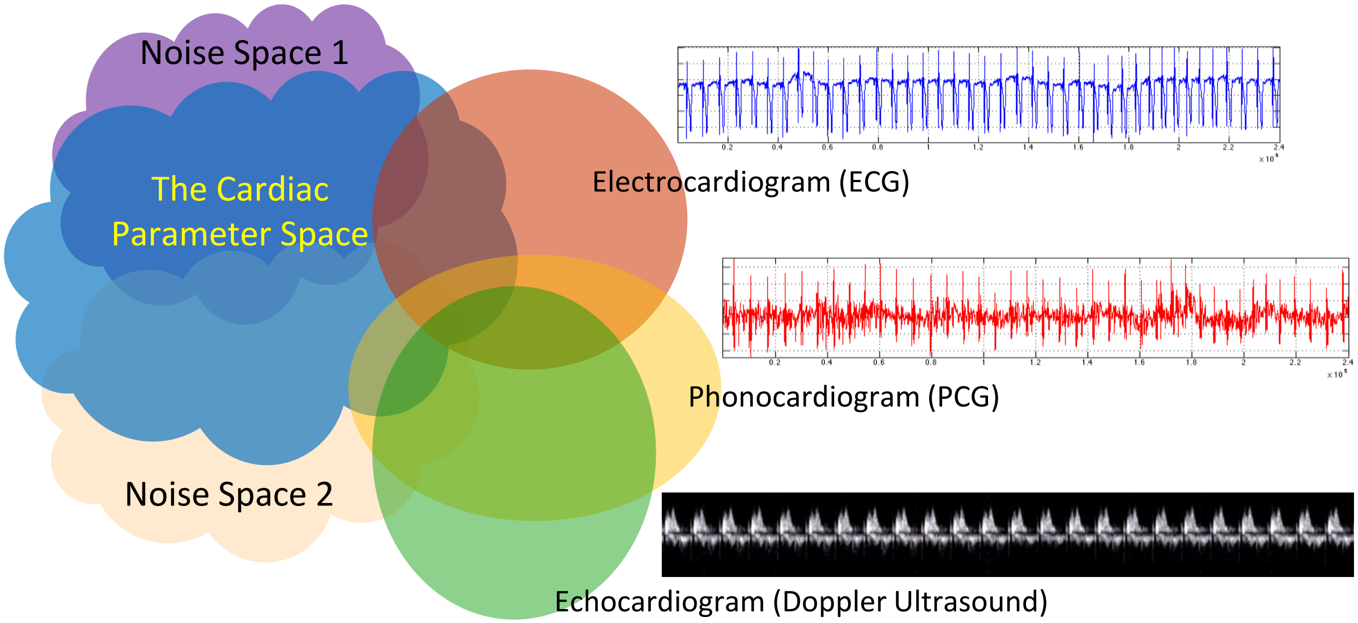
- **Objective:** Multimodality is used to obtain more knowledge of the concept of interest and to extract its parameters more precisely, using the modality overlaps, diversities, synergies and innovations.

- **Challenges:** Noise, mismatch/inconsistency, alignment, lags, missing segments, etc.

Example: Multichannel and Multimodal Cardiac Monitoring

Concept: The heart (as an electrophysiological organ)
Parameters of interest: Heart rate, QT-intervals, ST-segment, T/R ratios, S_1 and S_2 heart sounds and murmurs
Modalities: ECG, PCG, Doppler, MCG, Cardiovascular magnetic resonance imaging (CMR), etc.

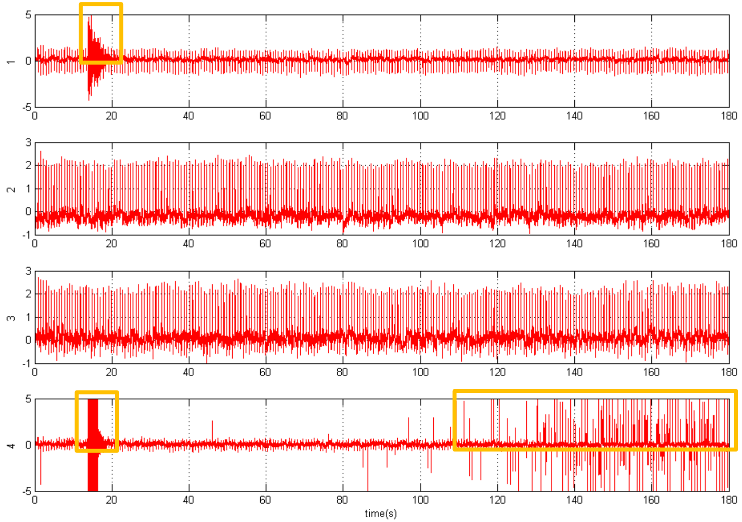




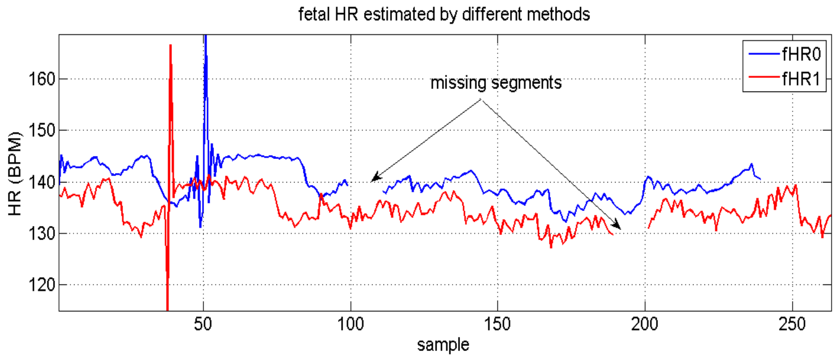
Methodological Challenges in Multimodal Analysis

Issues of interest: Modality alignment, overlap (redundancies, innovations), recovery (missing segments), fusion

Example: Multichannel ECG and heart rate time series



Missing (or noisy) segment recovery



Misaligned/missing segments/noisy

Required Background and Skills in our Lab

Courses: Stochastic process, Digital signal processing, Biomedical signal processing, Linear algebra, Optimization, Machine Learning

Programming Languages: Matlab, C++, Python

Bonus Skills: Electronics and PCB design, Hardware Description Languages (Verilog or VHDL)

Thank you!

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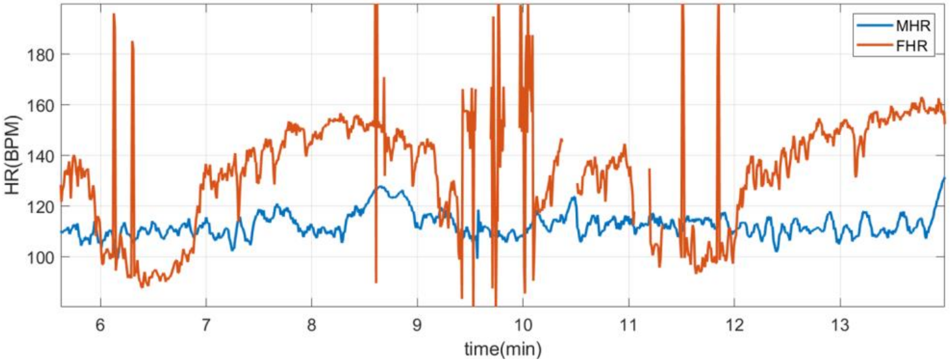
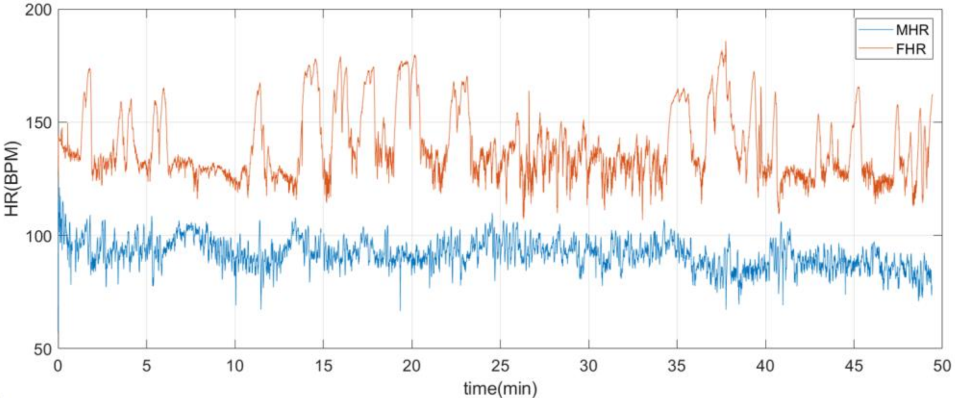
Robust Fetal Heart Rate Tracking

MHR-FHR crossings



Steep FHR variations



Theoretical Challenges in Multimodal Analysis

Fact: The information capacity of noisy channels/modalities are bounded
Challenge: Selection vs fusion between modalities; when and how?

Stereotypical example: Consider various noisy linear observations from a common source:

$$\mathbf{x}_1 = \mathbf{A}\cdot\mathbf{s} + \mathbf{n}_1 \text{ , } \mathbf{x}_2 = \mathbf{B}\cdot\mathbf{s} + \mathbf{n}_2\text{, } \mathbf{x}_3 = \mathbf{C}\cdot\mathbf{s} + \mathbf{n}_3\text{, } \ldots$$

Question: For the “optimal” estimation of **s**, which is best:

1) Select between the observations?
2) Fuse all observations as $[\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_3]$?
3) Use subsets: $\mathbf{x}_1$, $\mathbf{x}_2$, $\mathbf{x}_3$, $[\mathbf{x}_1, \mathbf{x}_2]$, $[\mathbf{x}_2, \mathbf{x}_3]$, etc.

Answer: From the estimation and information theoretical viewpoints (Cramér–Rao Lower Bound & Mutual Information), the answer is not trivial, even for the simplest linear data model and Gaussian noise

Where I come from…

And more recently….