National Technical University of Athens
Department of Electrical and Computer Engineering
Electronic Sensors Laboratory

"A Sensor Node for Non-Invasive Cardio-Respiratory Monitoring of Infants"

Ioannis A. Thanasopoulos
Georgios P. Mazarakis
Panayotis K. Kikiras
Ioannis N. Avaritsiotis

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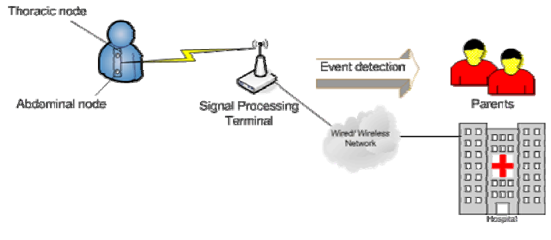
Presentation outline

- Description and requirements for a system for cardio-respiratory monitoring
- Technical description of the sensor
- Experimental method and practical issues
- Discrete Wavelet Transform & algorithm
- Results & conclusions

System overview

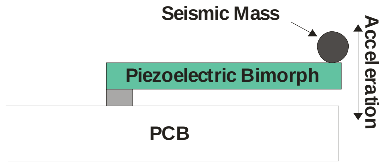


Design goals

- Non-invasive
- Reliable
- Low cost
- Compact
- Energy efficient

Technical description of the sensor

- Use of a bending mode piezoelectric accelerometer.
- Low-noise and compact sensor design
- Low power



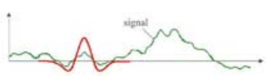
Measurement conditions

- Two sensors used for abdominal and thoracic movement monitoring
- Subject lying on their back, breathing normally
- Simulation of apnea events
- 20 sec data sets, acquired by oscilloscope
- Sampling Frequency at 100Hz

The Wavelet Transform

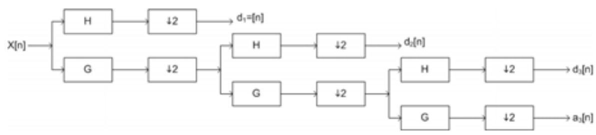
- Wavelets
  - Localized wave-like functions

- Shifting/ dilation
- Quantification of similarity



Discrete Wavelet Transform(1)

- Mallat's Algorithm
  - Recursive filtering with a high pass (H=h{n})and a low pass filter (G=g[{n})
  - Downsampling at each level
  - N+1 sets of coefficients (N=level of decomposition)

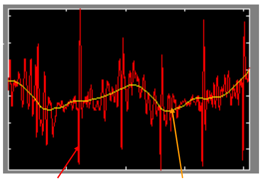


Discrete Wavelet Transform[2]

- Each set of coefficients corresponds to a different frequency component
- Reversible procedure (iDWT)
- Efficient for:
  - Data compression
  - De-noising
  - Time-frequency analysis
  - Feature extraction

Signal components

- Two significant frequency components



Selection of the appropriate wavelet

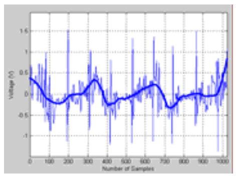
- Time-frequency localization
- Computational preservation
- Daubechies Family

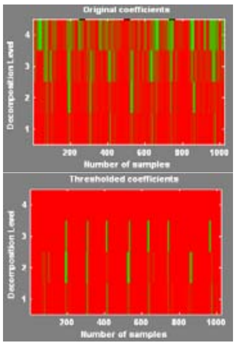
Daubechies D8

D8 Wavelet Coefficients
0.32580343
1.01094572
0.89220014
-0.03957503
-0.26450717
0.0436163
0.0465036
-0.01498699

Results – Heart pulses

- Data sets of 1024 samples
- Decomposition at the 4th level
- Denoising of the coefficients



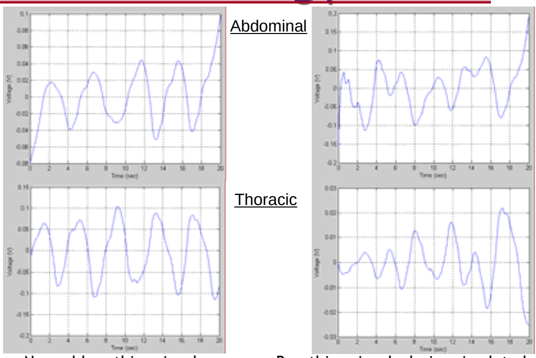


Results – Breathing pattern(1)

- Breathing pattern revealed at the 6^{th} level approximation coefficients
- The similarity between the thoracic and the abdominal pattern as a means of detecting respiratory obstruction
- Calculation of the normalized cross-correlation coefficient, $\rho_{1,2}$ between:
  - the signal acquired from the abdominal node and
  - the signal acquired from the thoracic node

$$\rho_{1,2}(j) = \frac{\sum_{n=0}^{N-1} x_1(n) x_2(n+j)}{\left[\sum_{n=0}^{N-1} x_1^2(n) \sum_{n=0}^{N-1} x_2^2(n) \right]^{1/2}}$$

Results – Breathing pattern(2)



Normal breathing signals
$\rho = 0.79$

Breathing signals during simulated apnea
$\rho = 0.18$

Conclusions

- Two piezoelectric accelerometers instead of bulky equipment
- Simultaneous monitoring of cardiac and respiratory signals
- Eventual integration of the nodes and sensors into the baby clothes – unobtrusive monitoring of sleep