



**Engineering Medical Research** 



## Sparse Representation of ECG Signals Using Over-complete dictionaries for Physiological Analysis







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- While temperature, pulse, respirations, and blood pressure are all objectively measure; <u>pain is</u> <u>inherently subjective</u>.
- failure to properly assess pain is a common cause of its poor control and lack of treatment in patients in different settings
- It has been termed "the fifth vital sign" and is now being evaluated and registered in the patients' charts during routine checkups.





## Our objective is to find correlation between the ECG and the Heart rate to pain by novel analysis methods







#### Points of interest for advanced analysis

















-2000

Window Size

15000

10000 ECG 5000

•

71.5

5

71.5

72

72 72.5

Set Limit

72.5

73

73

73.5

Zoom

73.5

74

74

74.5

Close

74.5

75

75

75.5

75.5

Mean RR

76

76

#### Identifying the R waves

#### **ECG** Analysis

• Forming the R-R wave



## Why bother? - HRV for Pain Analysis

🥟 heart rate variability pain - PubMed result - Windows Internet Explorer			
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<ul> <li>Heel-Lancing in Newborn</li> <li>Weissman A, Aranovitch Pediatrics. 2009 Oct 19. [Epu PMID: 19841119 [PubMed - 3 Related articles</li> </ul>	ns: Behavioral and Spectral Analysis Assessme M, Blazer S, Zimmer EZ. ub ahead of print] as supplied by publisher]	ent of Pain Control Me	thods.
<ul> <li>Exploring non-invasive methods to assess pain in sheep.</li> <li>Stubsjøen SM, Flø AS, Moe RO, Janczak AM, Skjerve E, Valle PS, Zanella AJ. Physiol Behav. 2009 Oct 13. [Epub ahead of print] PMID: 19833144 [PubMed - as supplied by publisher] Related articles</li> </ul>			

### Fourier Transform

- The Fourier transform (FT) is an operation that transforms one complex-valued function of a real variable into another.
- That of the new function is frequency, and so the Fourier transform is often called the frequency domain *representation* of the original function.
- The Fourier transform decomposes a function of time (a signal) into the frequencies that make it up

### Fourier Transforms





### The Wavelet Transform

- A wavelet series is a representation of a square integrable (real - or complex - valued) function by a certain orthonomal series generated by a fixed and known pattern known as a wavelet.
- Unlike FT, the continuous wavelet transform possesses the ability to construct a time-frequency representation of a signal that offers very good time and frequency localization.

### The Wavelet Transform

• The Haar Wavelet





### The Wavelet Transform





# • Fourier Transforms – signal Harmonics

## • <u>Wavelets</u> time dependant acute change

## **Orthogonal Matching Pursuit**

- OMP is a greedy least-squares procedure that chooses the dictionary vectors one at a time.
- At each step (k=1) a single vector from the combined dictionary that has the highest correlation with b is chosen by solving the following problem:

$$\begin{split} \min_{v} \left( \min_{c} \|b - cv\|_{2} \right) \\ v \text{ is a vector of the matrix } [A_{1} | A_{2}] \text{ and } c \in R \\ \hat{b}_{1} \text{ be the resulting best approximation of } b \\ e_{1} &= b - \hat{b}_{1} \text{ be the error after the first step} \\ \text{ In the } k \text{-th step the next vector is determined by solving} \\ \min_{v} \left( \min_{c} \|e_{k-1} - cv\|_{2} \right) \\ v \text{ is a vector of the matrix } [A_{1} | A_{2}] \text{ and } c \in R \end{split}$$

## The Cold Pressor Experiment

- 15 healthy adult volunteers participated in this experiment.
- The subjects were sampled during 10 minutes of rest as baseline. Then they dipped their dominant hand into icy water to produce acute pain and each subject kept the hand till the point of maximal pain and voluntarily took the hand out.
- Sampling ended when the subject was relieved of any pain













## **Only Wavelets**















## **Only Wavelets**



200 250 300 350

400 450 500

0.

150







### Experiment #2

- UCSD VA
   Anasthesia
   department
   Pain research
- Controlled pain was inflicted on 15 subjects by capsaicin injection to the right thigh during ECG sampling, correlated to blood cortisol and substance P levels.













## Only Fourier - Sliding window



## Only Wavelet

















## Conclusions

- HRV is personal dependant
- WT Suggestive
- OMP best representation

## But.... This is not all.....

## Arrhythmia Prediction

 Initial assessment: RR intervals from patients who experienced <u>ventricular arrhythmias</u> were made public by Medtronic Inc. on the Web (the Physionet database).

 Those patients' data were analyzed using the Wavelet transform and the OMP algorithm with an overcomplete Fourier/Wavelet dictionary

## <u>Combined baseline and pre-arrhythmia</u> <u>signals</u>









Only WT

















OMP

## Cool ? – wait.....

