Linear Modelling of Cardiovascular Parameter Dynamics during Stress-Test in Horses

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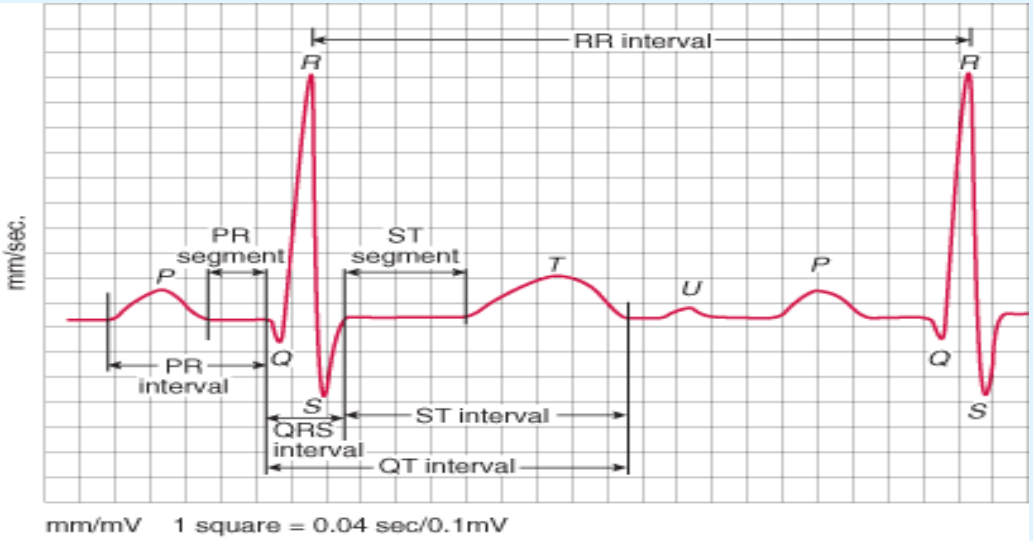
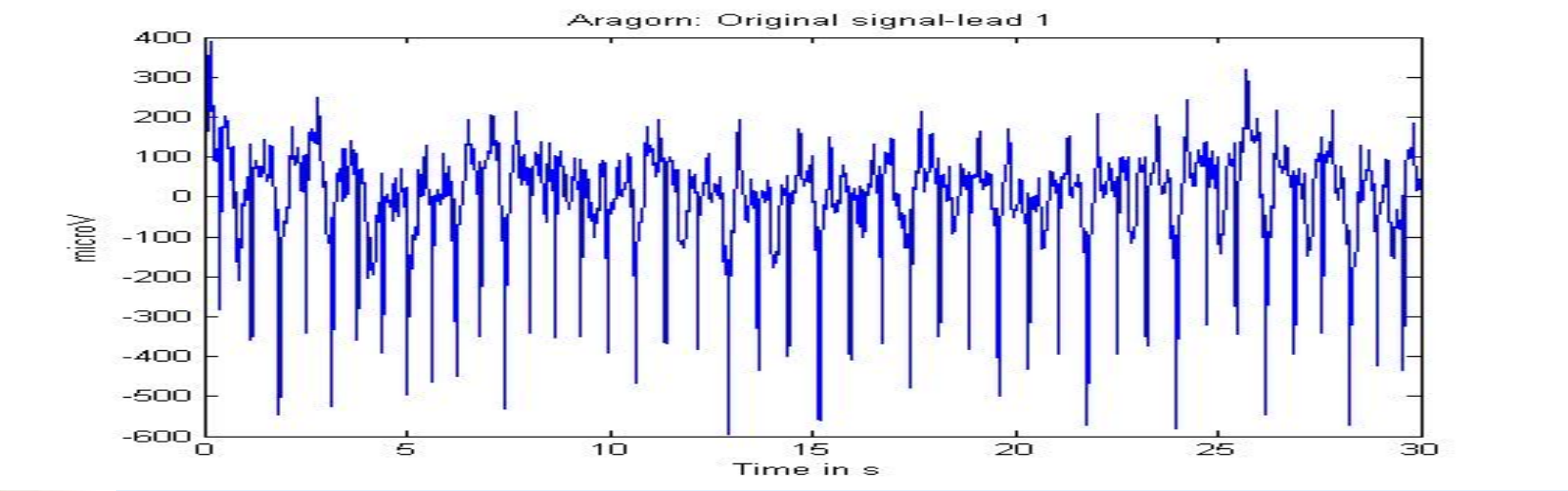
MOTIVATION

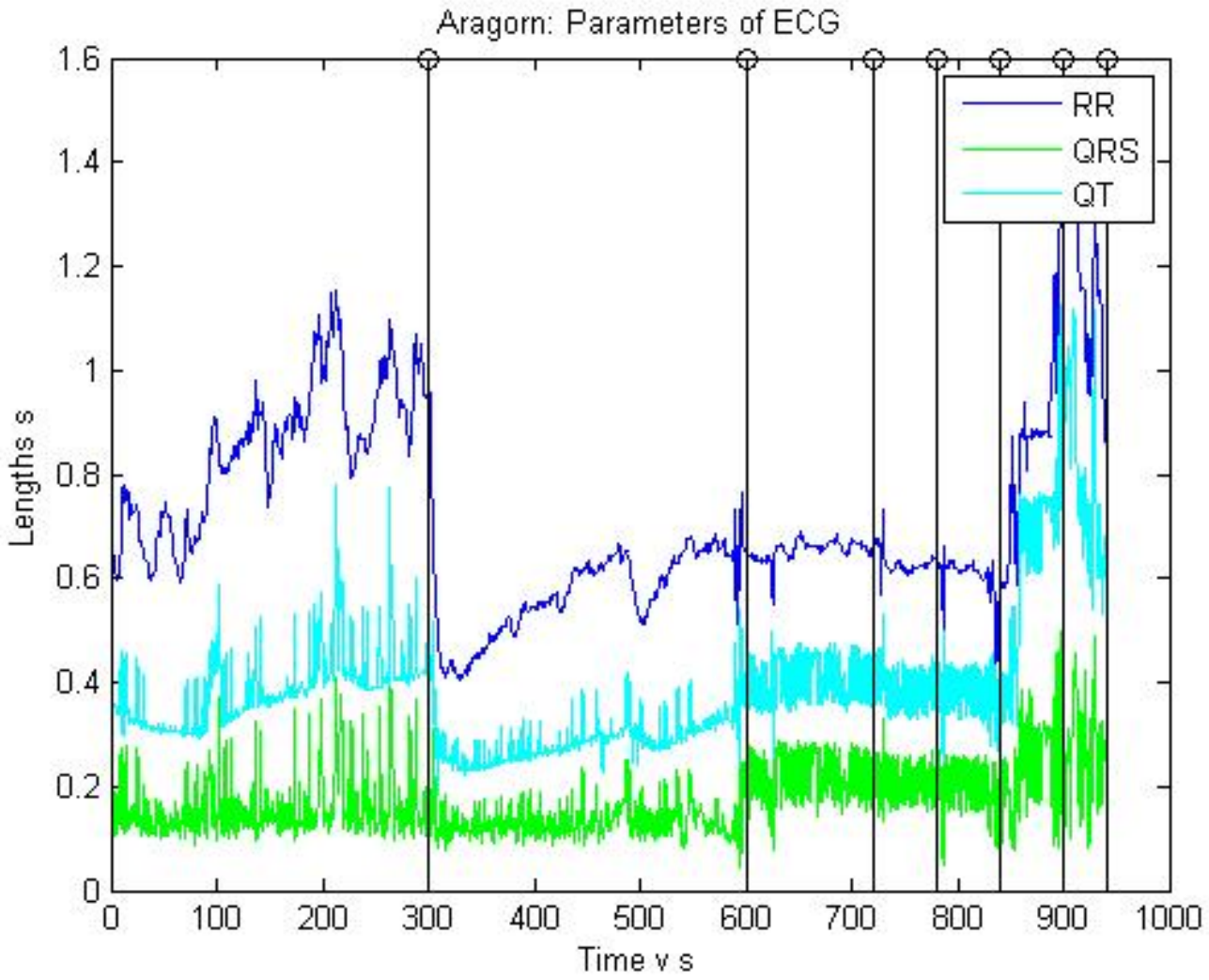
- To describe the dynamics of cardiovascular parameters of ECGs.
- To find the differences in dynamics of parameters in horses under different conditions.
- To find a function of ECG parameters describing the level of fitness in horses, which will be helpful by assessment the diagnose of the horse.

ECG SIGNAL


RR interval
R
R
PR segment
ST segment
P
T
U
P
Q
Q
S
S
PR interval
QRS interval
ST interval
QT interval
mm/sec.
mm/mV 1 square = 0.04 sec/0.1mV

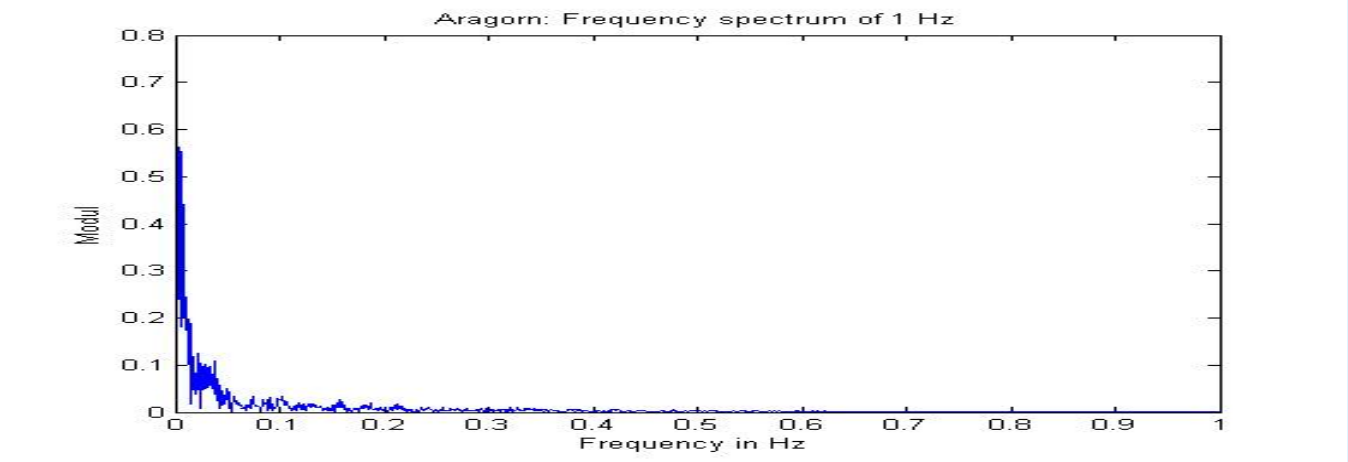

Aragorn: Original signal-lead 1
microV
400
300
200
100
0
-100
-200
-300
-400
-500
-600
0
5
10
15
20
25
30
Time in s

ECG SIGNAL PARAMETERS



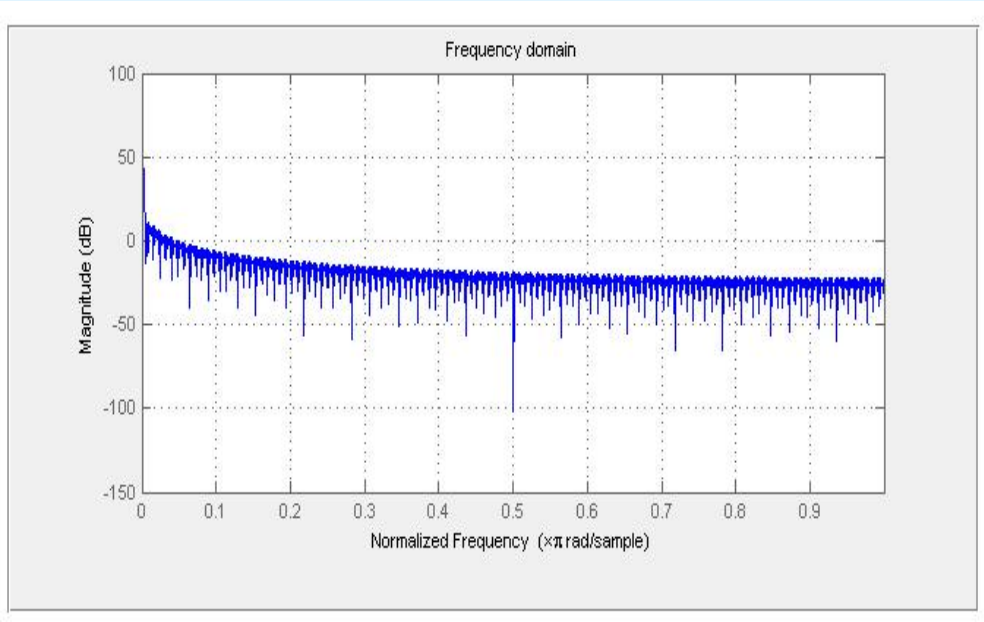
SIGNAL PROCESSING- TREND

- Frequency approach
- Identify physiological processes by vets or noise
- Figure out the frequency spectrum of signal using the Fourier transformation
- Find in spectrum the first cluster of significant frequency, which represents the trend component



SIGNAL PROCESSING - TREND

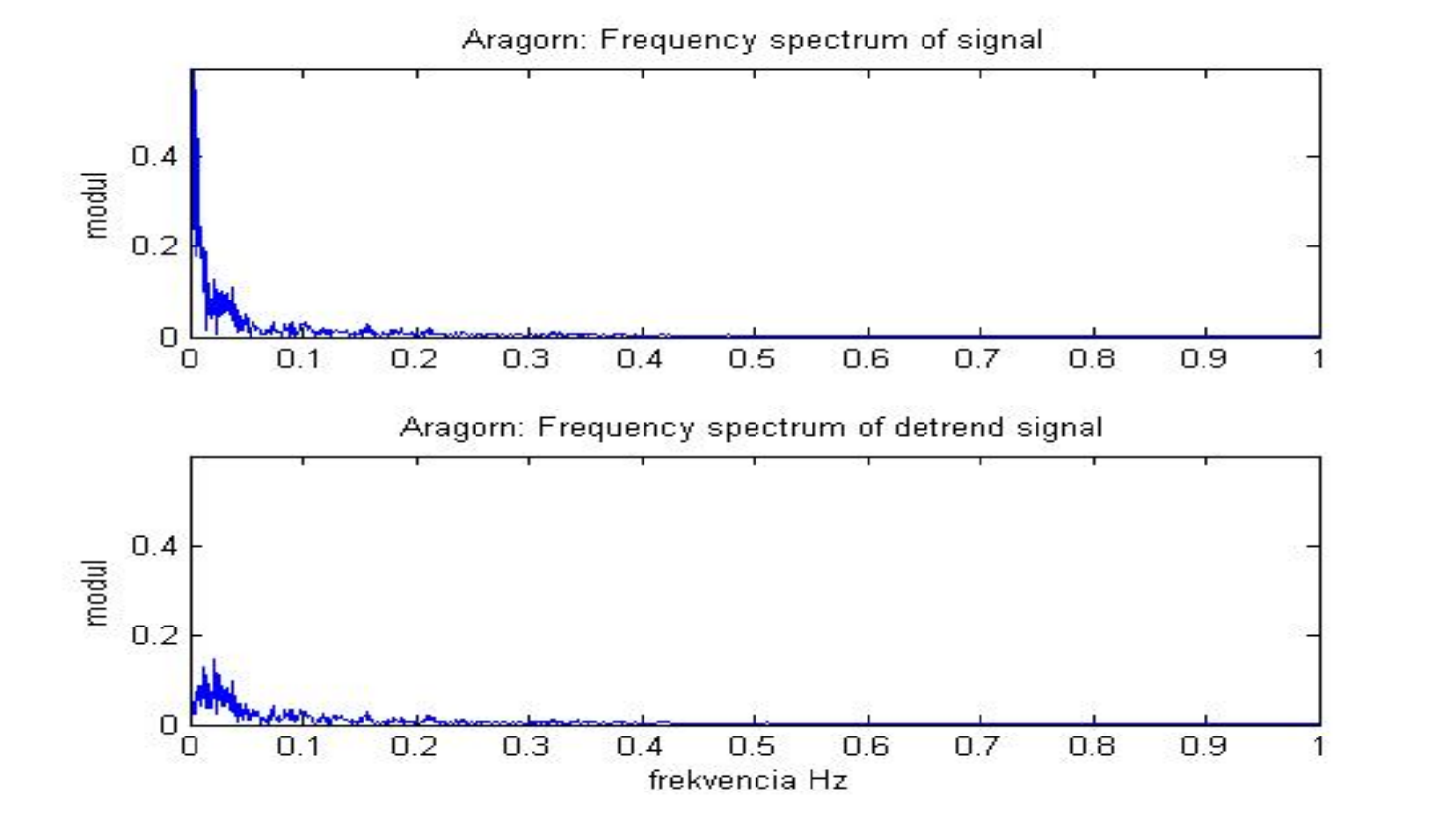
- Design the suitable low pass filter
- Low pass filter:
  - Used degree: 900
  - Hamming window



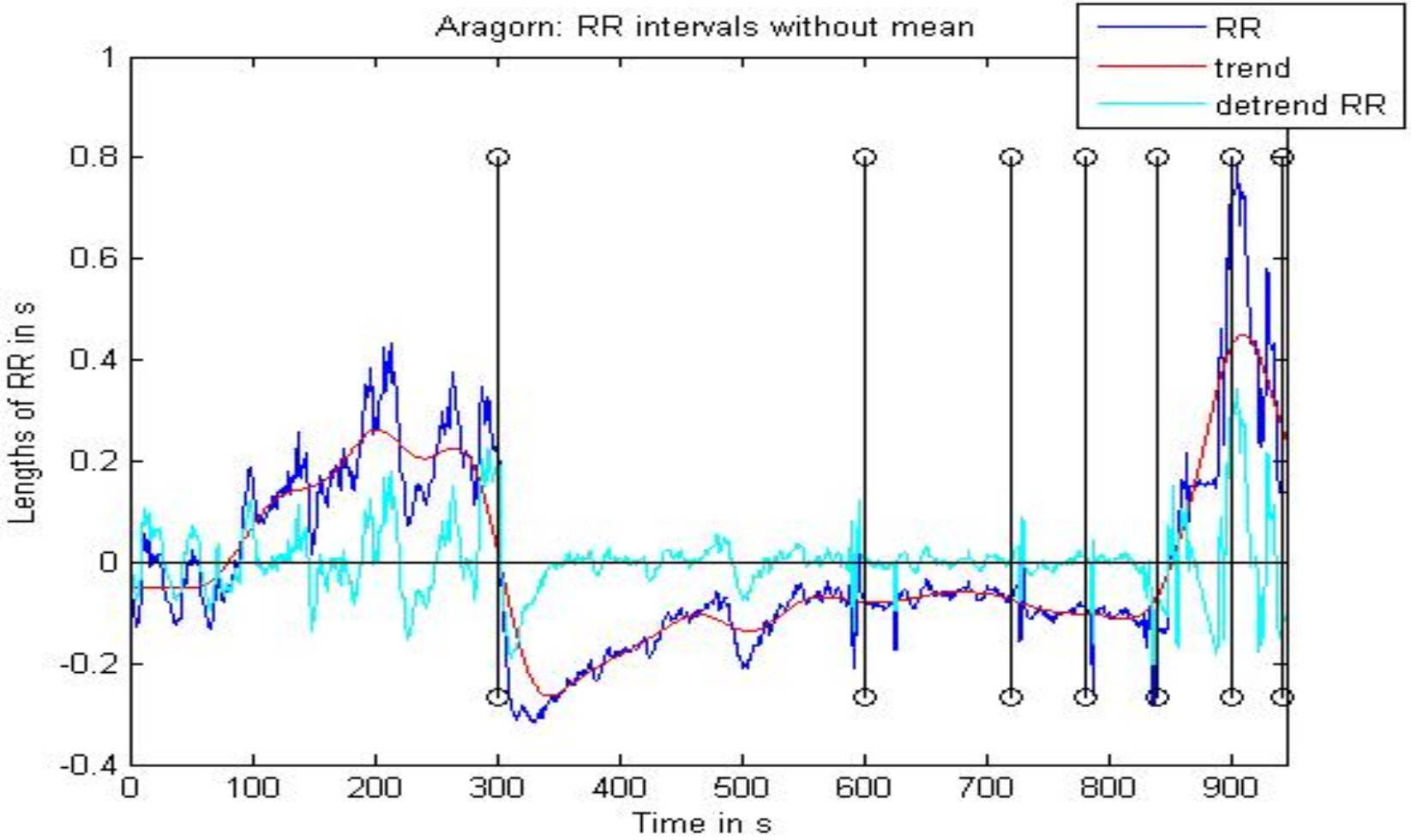
- Obtain the stationary signal
- Trend - low-pass filtered signal of RR intervals

PROCESSING SIGNAL-TREND

- Frequency spectrum



PROCESSING SIGNAL-TREND



PROCESSING SIGNAL- AR MODEL

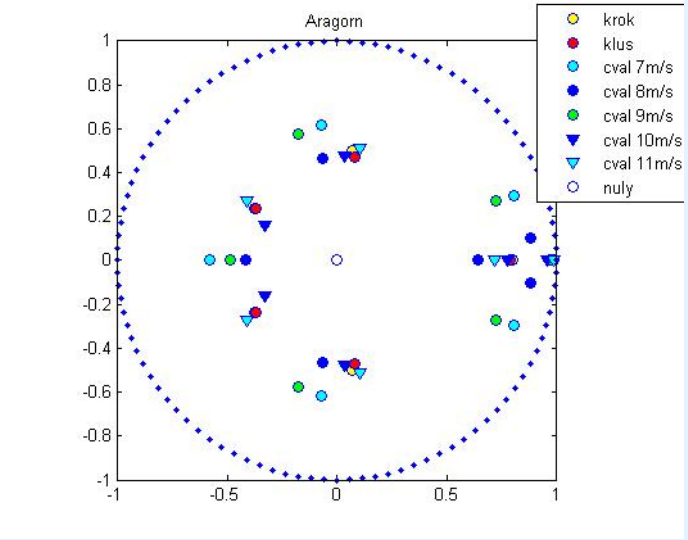
- Signal was distributed to the parts responding to the individual steps of stress-test-usually 6 or 7 parts
- The suitable ARMA model was finding for all parts together
- For the classification of ARMA model was used plots of ACF (autocorrelation function) and PACF (partial autocorrelation function)
- The used model was AR(6):

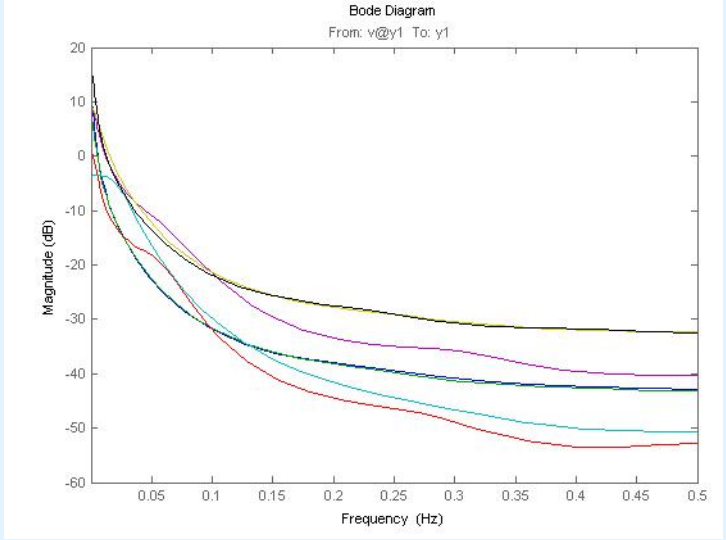
$$Y_t = -\alpha_1 Y_{t-1} - \alpha_2 Y_{t-2} - \alpha_3 Y_{t-3} - \alpha_4 Y_{t-4} - \alpha_5 Y_{t-5} - \alpha_6 Y_{t-6} + \varepsilon_t$$

$$\varepsilon_t \sim WN(0, \sigma^2)$$

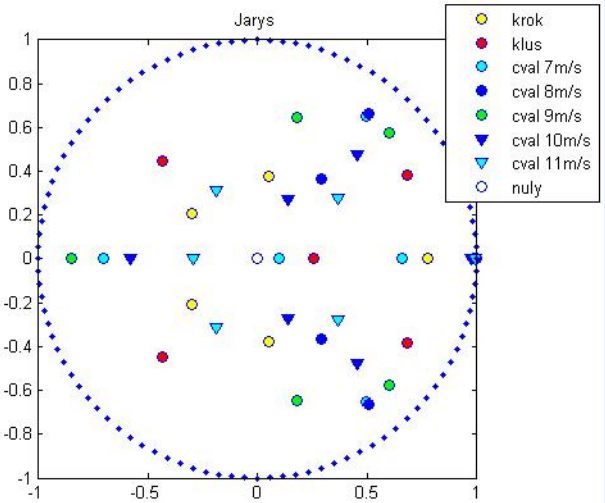
DYNAMICS OF PARAMETERS

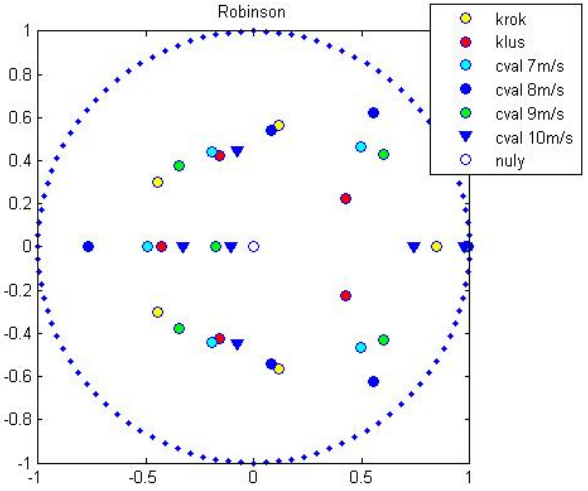
- For every step of stress-test:
- $Y_t = -\alpha_1 Y_{t-1} - \alpha_2 Y_{t-2} - \alpha_3 Y_{t-3} - \alpha_4 Y_{t-4} - \alpha_5 Y_{t-5} - \alpha_6 Y_{t-6} + \varepsilon_t$
- Transfer function:
- $$H(z) = \frac{z^6}{z^6 + \alpha_1 z^5 + \alpha_2 z^4 + \alpha_3 z^3 + \alpha_4 z^2 + \alpha_5 z + \alpha_6}$$
- Zeros and poles of H(z):

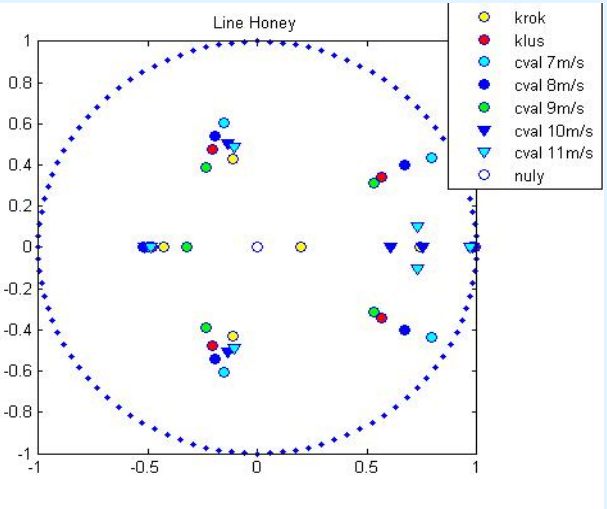


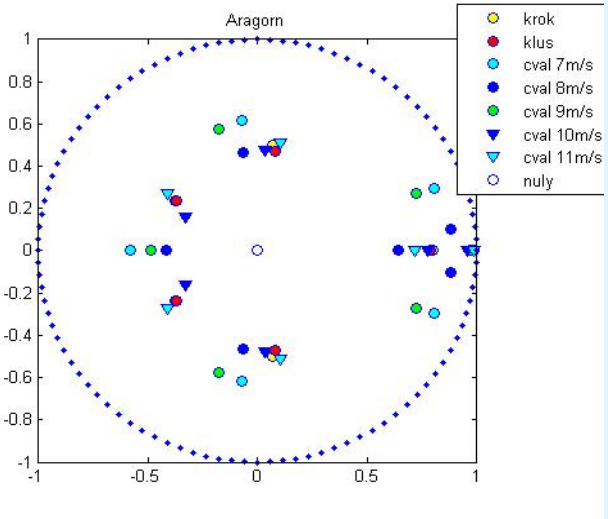


COMPARING DYNAMICS OF PARAMETERS









CONCLUSION

- The moving and distribution of transfer function poles are different for horses with different level of fitness

- Next:
  - To find regression model describing the move of this poles
  - To model next ECG signal parameters
  - To find the function describing the level of fitness in horses

REFERENCES

- Forbelská, M.: Stochastické modelování jednorozmerných časových řad. Brno: MU, 2009. ISBN 978-80-210-4812-6
- Harris, F. J.: On the use of windows for harmonic analysis with the discrete Fourier transformation. Proceedings of the IIE, vol. 66, No. 1, January 1978.
- Physics-Sheard, P. W. and col.:, Frequency domain analysis of heart rate variability in horses at rest and during exercise. Equine veterinary journal, 2000.
- Cirkytova, E. and col.: Exercise capacity in different breeds of horses. Equine exercise physiology 3: 37-40, 1991.
- Svačinová,J.: Evaluation of Stress Test ECG Signal Parameters in Horses. [Diploma Thesis], Brno, Masaryk University, 2011. (in Czech)
- Box, G. E., Jenkins, G. M., Reinsel, G. C. : Time Series Analysis Forecasting and Control. 4th. ed., Hoboken, New Jersey: John Wiley & Sons, Inc. 2008. ISBN 978-0-470-27284-8.

- Thanks for the attention:)
- ... and have a nice day!