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Project title: "ThinkBS - Promoting Deep and Wide Thinking / Early Dual Degrees in Basic Sciences"

Summer School - Debrecen

Time: July 4, Monday, 2022 - July 15, Friday
Online classes on worksdays of July 4-8, 9:00 -11:30 AM, and 1:00 – 3:30 PM
Project work and presentation on the week July 11-15

Project

‘Mathematics of Technical Diagnostics’

Course materials: tovabbkepzes.unideb.hu

Exercise 01

Determination of frequencies in a signal on the basis of a sample (any software can be used for the calculations, e.g. MS Excel Analysis ToolPack)

The following values has been obtained in sampling process with the sampling frequency $f_s = 200\ [Hz]$:

k	sampled signal	k	sampled signal
0	0,0000	16	3,1416
1	0,1963	17	3,3379
2	0,3927	18	3,5343
3	0,5890	19	3,7306
4	0,7854	20	3,9270
5	0,9817	21	4,1233
6	1,1781	22	4,3197
7	1,3744	23	4,5160
8	1,5708	24	4,7124
9	1,7671	25	4,9087
10	1,9635	26	5,1051
11	2,1598	27	5,3014
12	2,3562	28	5,4978
13	2,5525	29	5,6941
14	2,7489	30	5,8905
15	2,9452	31	6,0868

See **`Exercise01.xlsx`**, use decimation sign '.' in the English version.

Give the frequencies in the spectrum.

Exercise 02

A vibration is given by the position-time function

$$x(t) = 42.8 \cdot \sin(652 \cdot t + 0.34) + 105$$

Give the values in listed below:

amplitude	
maximum	
minimum	
period	
frequency	
angular frequency	
phase	

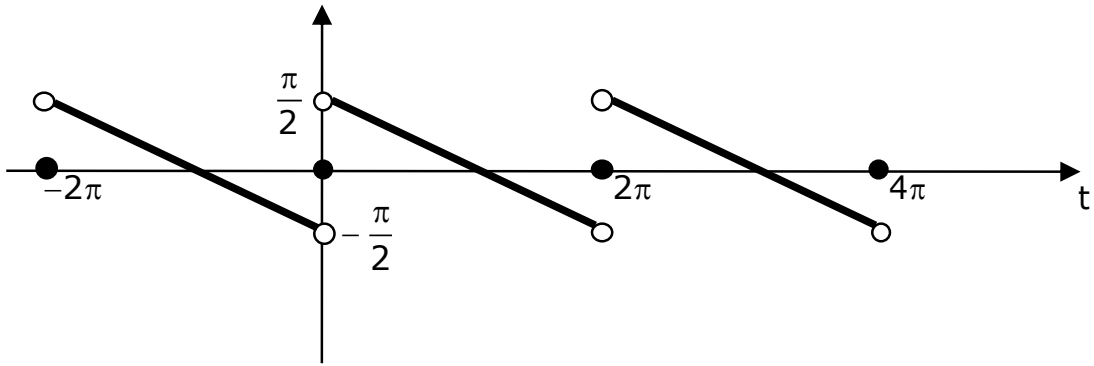
Exercise 03

Show that

$$\sum_{n=0}^{2} e^{i\cdot 2\pi\cdot\frac{n}{3}} = 0$$

Exercise 04

Compare the ‘similarity’ of function f given by the following diagram



with functions:

$$x_1(t) = \sin(2 \cdot t)$$
$$x_2(t) = \sin(5 \cdot t)$$
$$x_3(t) = \sin(10 \cdot t)$$

Exercise 05

Give the sum of the first 5 terms in the Fourier series (with respect to the trigonometric system) of function whose one period is given by

$$x(t) = \begin{cases} 3 & \text{if } 0 \leq t < 4 \\ -1 & \text{if } 4 \leq t < 7 \end{cases}$$

Exercise 06

Give the norm and the inner product of functions

$$x_1(t) = e^{i \cdot \frac{8\pi}{T} \cdot t} \quad \text{and} \quad x_2(t) = e^{i \cdot \frac{14\pi}{T} \cdot t}$$

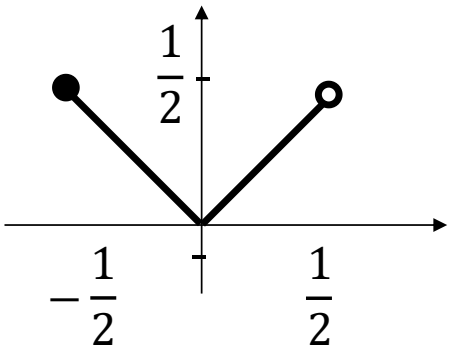
in the space of T-periodic functions $L_2([0, T])$

Exercise 07

Calculate the Fourier coefficient $\hat{x}_3$ of the 1-periodic function x defined as

$$x(t) = |t|, \quad -\frac{1}{2} \leq t < \frac{1}{2}$$

with respect to the exponential system.



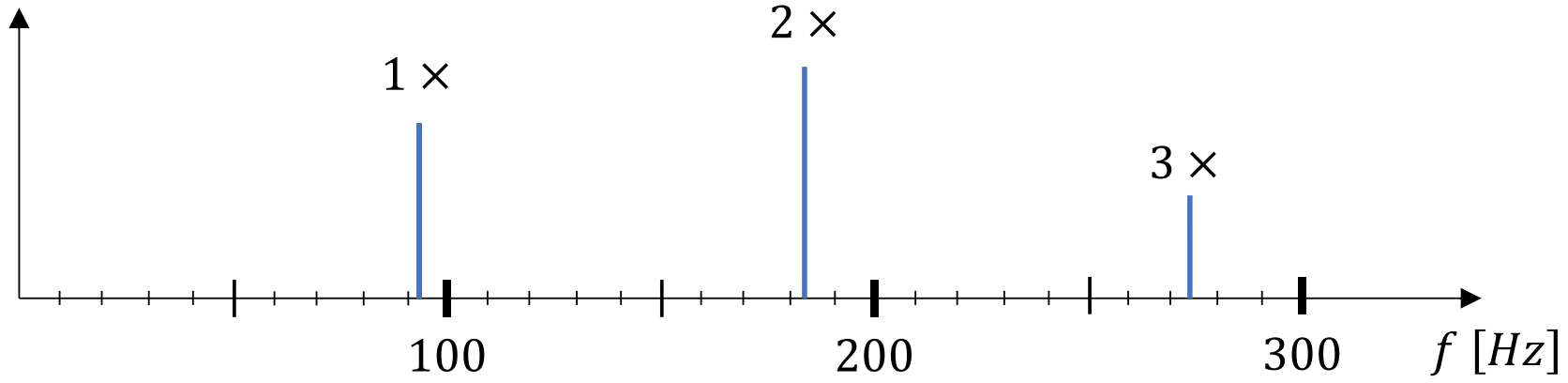
Exercise 08

The fault frequency coefficients of a bearing are given in the table

fault type	coefficient
outer ring	3.58
inner ring	5.74
ball	2.24
cage	0.85

The rotational speed of the shaft is 950 rpm.

Which element of the bearing is damaged on the basis of the following vibration spectrum:



Exercise 09

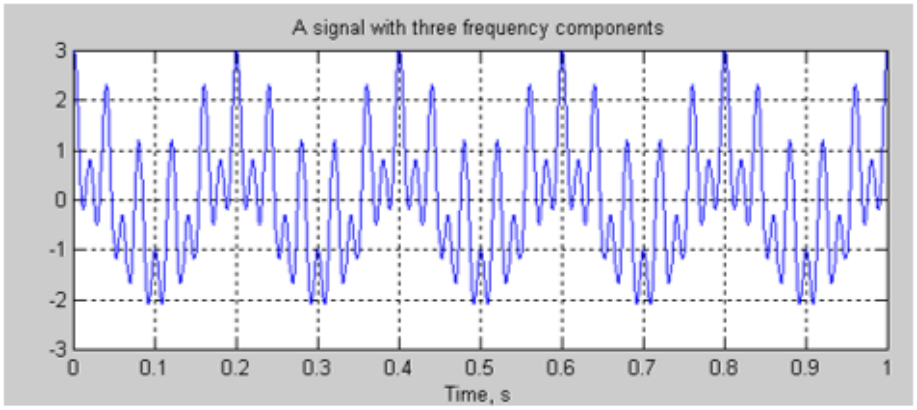
Determine the discrete Fourier transform of the sampled signal

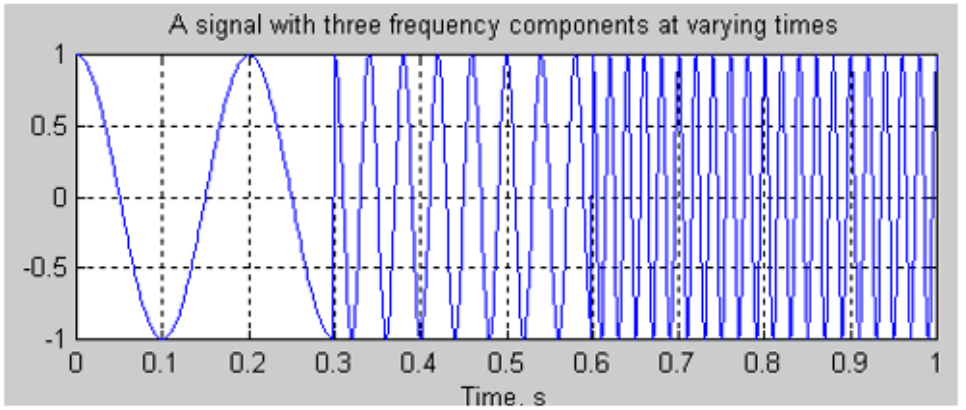
k	0	1	2	3	4	5	6	7
$x[k]$	3	-4	0	9	-2	0	-5	0

with matrix multiplication.

Exercise 10

Make a comparison of the figures below. Which one is the non-stationary signal and which analysis methods are the best for investigating the non-stationary signals?





Exercise 11

Generate a data set of 50 samples in MS Excel. Calculate the following statistical parameters in MS Excel.

- Mean
- Skewness
- Kurtosis

More help: https://www.youtube.com/watch?v=v5P4iUj_eoM

Exercise 12

Write the steps of the STFT analysis. What is the application fields of the STFT analysis?

(1)

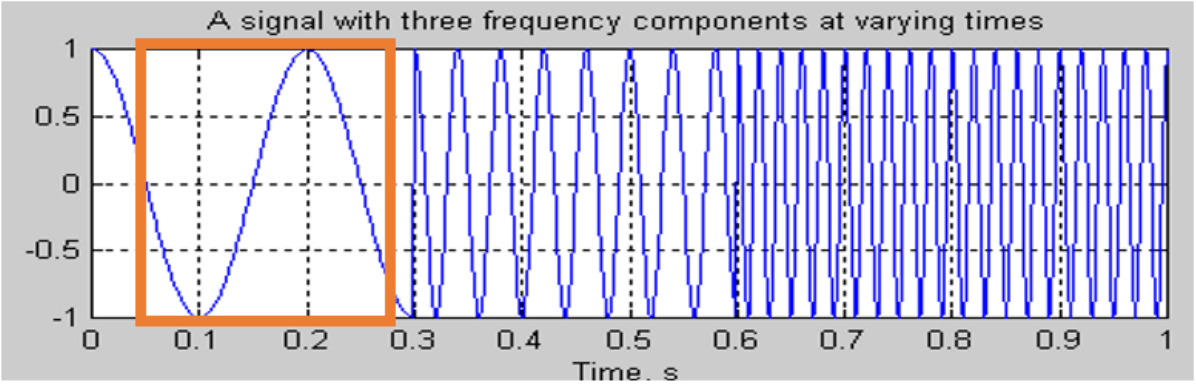
(2)

(3)

(4)

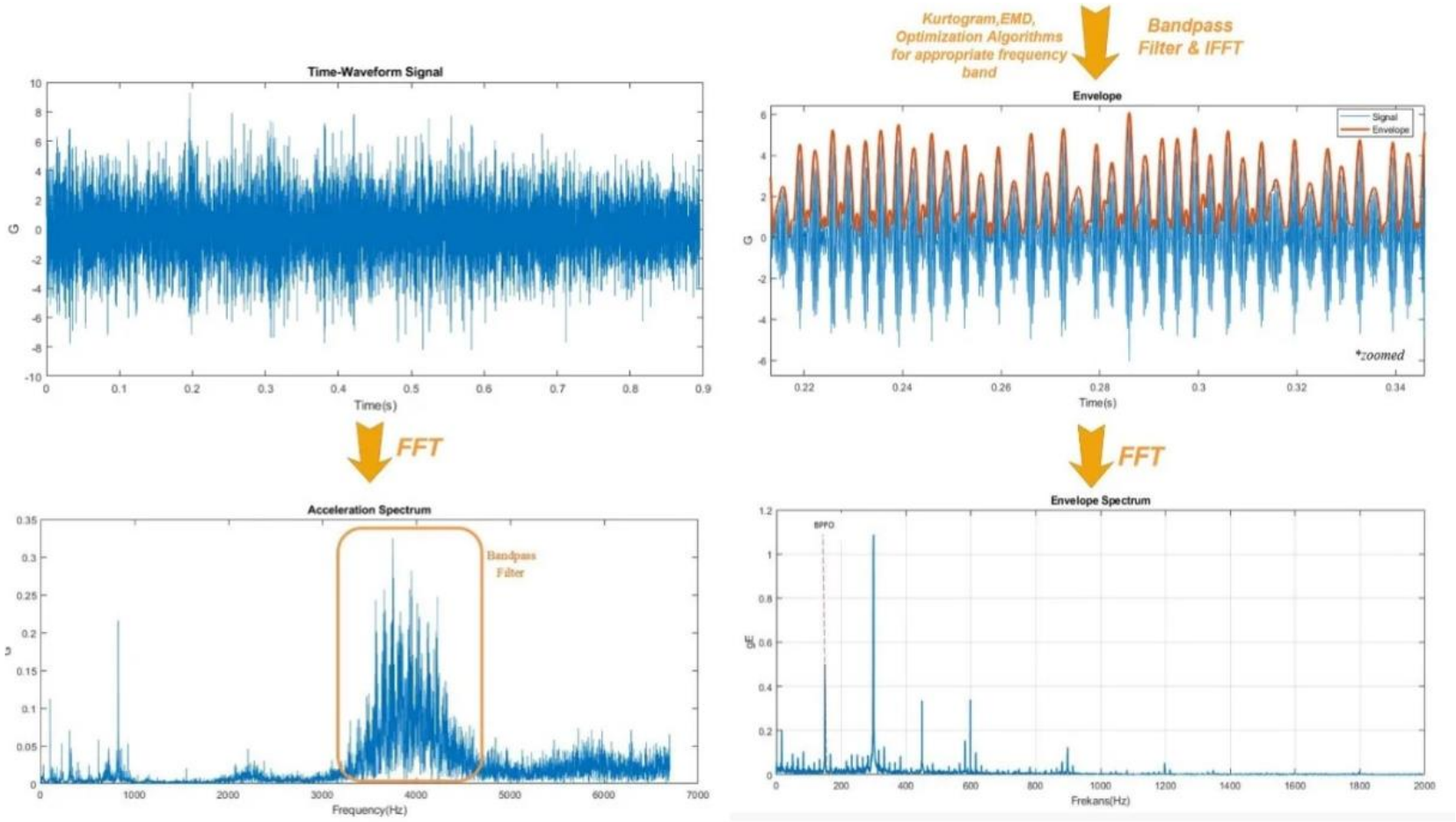
(5)

(6)



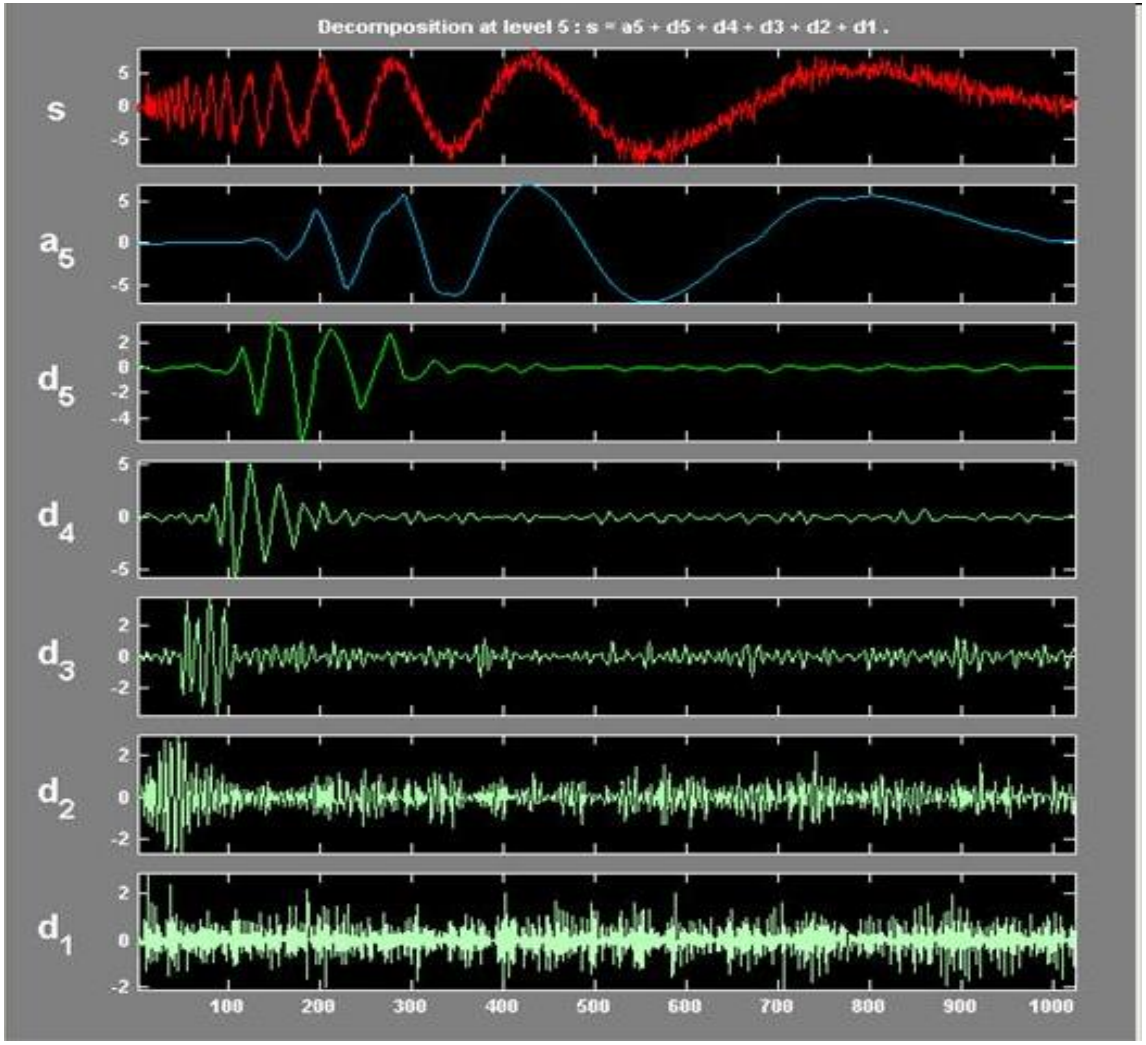
Exercise 13

What is the name of the analysis below? Describe it step by step following the figures.



Exercise 14

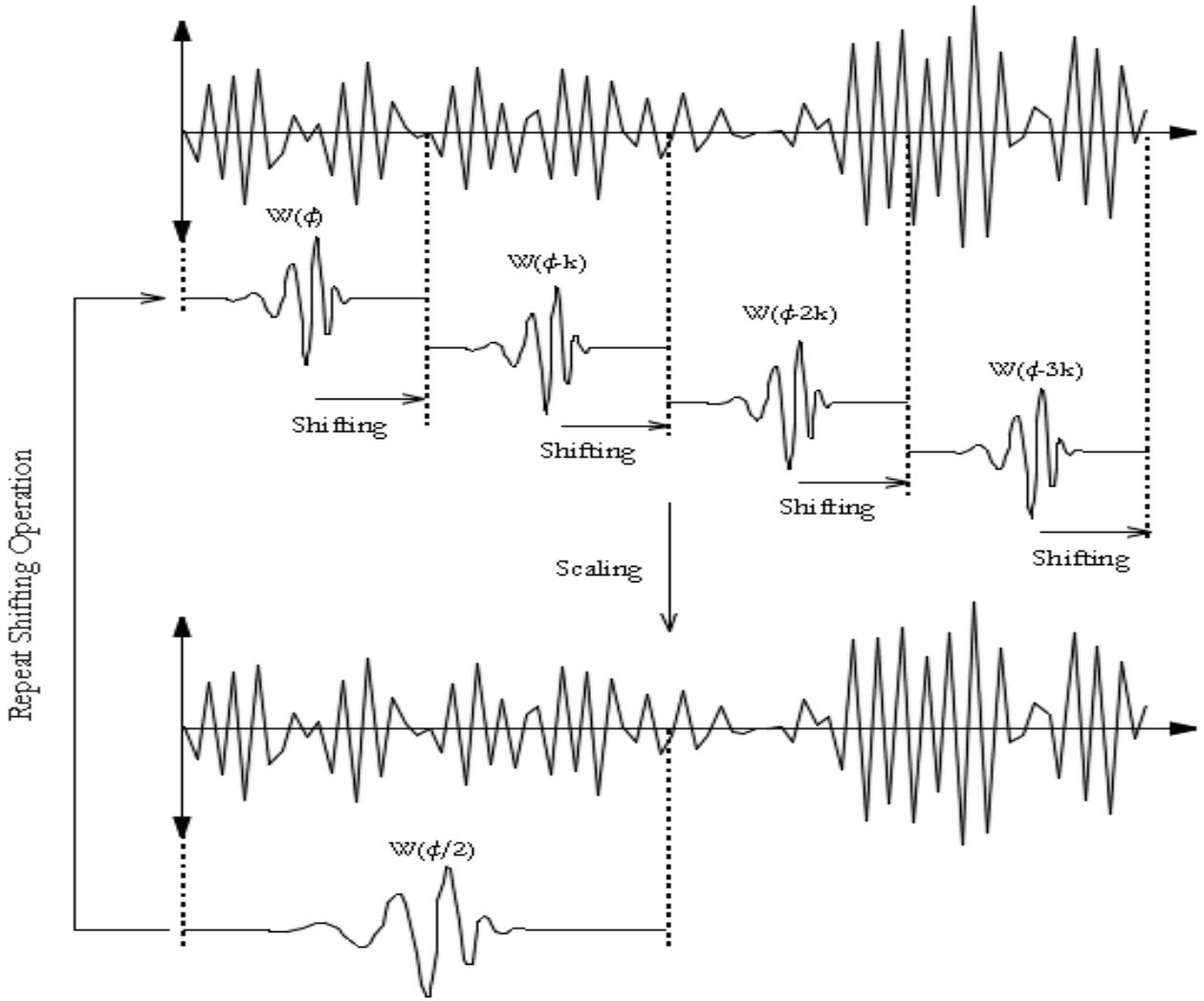
Explain the figure below. What is the name of the method that is used in the analysis? What do the different levels (s, d_1, d_2, d_3, d_4, d_5, a_5) mean?



Exercise 15

What are the role of shifting and scaling in the wavelet analysis following the figure below?

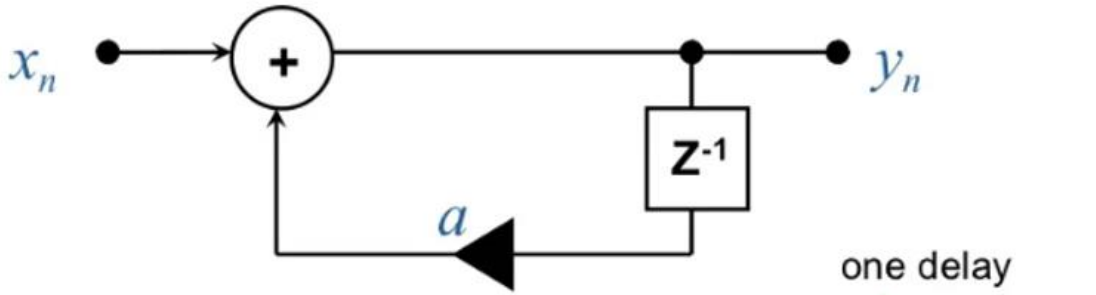
What kind of wavelets are used for practical analysis of the digital signals?



Exercise 16

Write the mathematical formula of the digital filter in the red rectangle and write a short explanation about it. What main filter parts are used in this application?

First-order recursive filter:

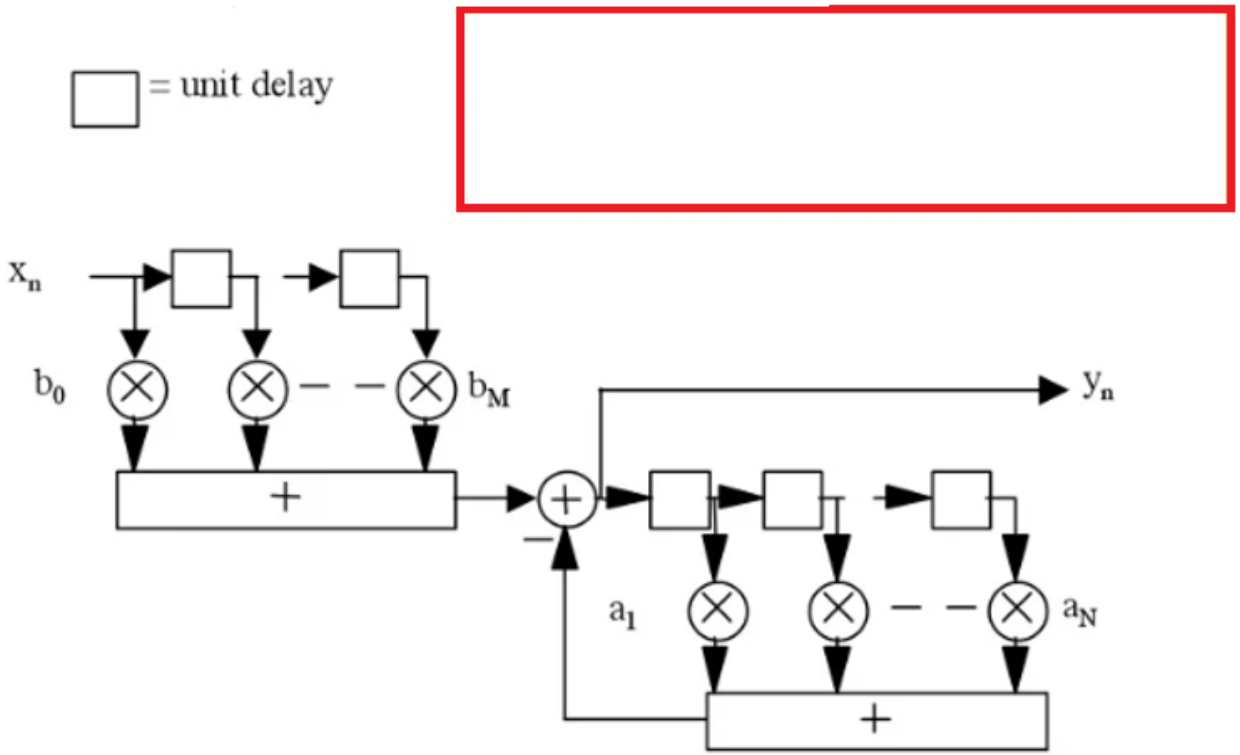


Example of feedback implemented in a digital filter

one delay ⇨ first-order

Exercise 17

Write the mathematical formula of the digital filter in the red rectangle and write a short explanation about it. What main filter parts are used in this application?



Exercise 18

What is the name of this mathematical formula and what is the purpose of it in digital filter theory?

$$H(z) = \frac{Y(z)}{X(z)} = \frac{\sum_{k=0}^{M} b_k z^{-k}}{1 + \sum_{k=1}^{N} a_k z^{-k}}$$

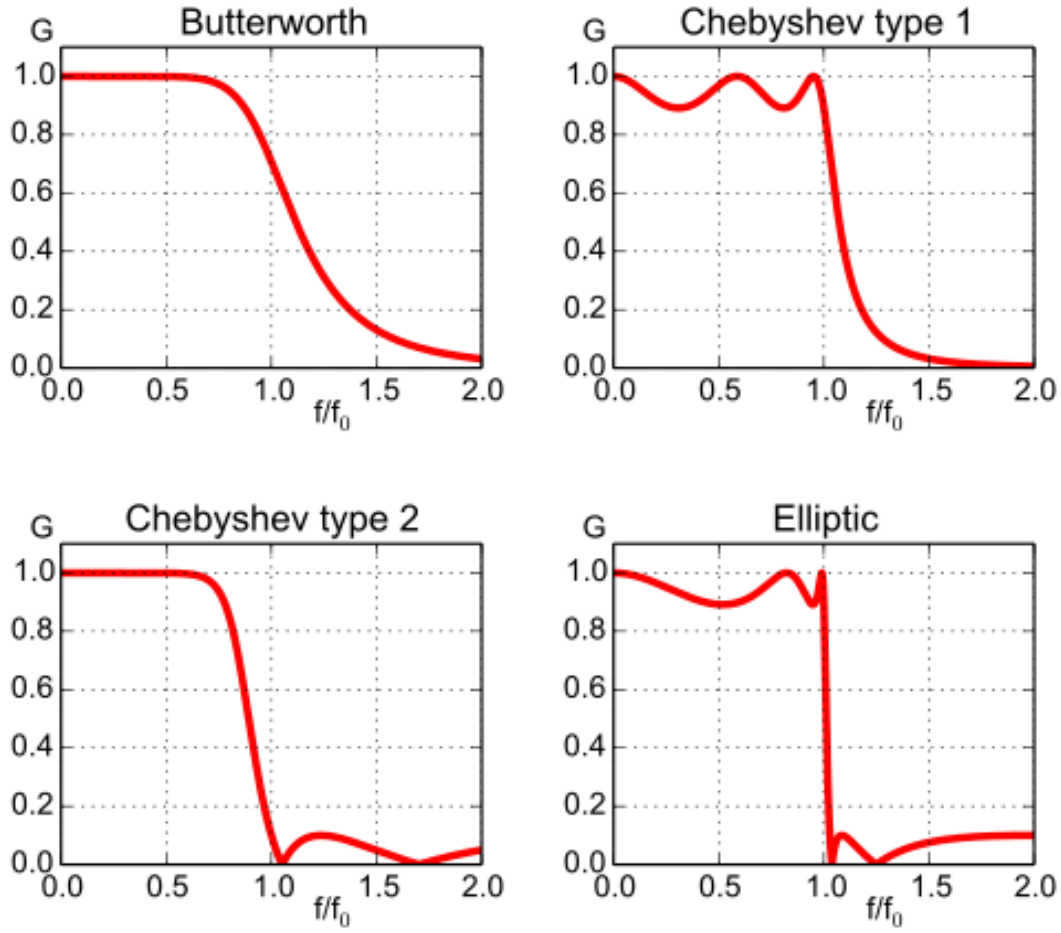
Exercise 19

a. / Describe the following IIR filters in the figures bellow taking into consideration their:

- Slope
- Attenuation
- Ripple
- Smoothness

b./ Write application fields where these IIR are considered to be more practical than FIR filters.

c./ Which filters need filter design and the calculation of the filter coefficients?


Butterworth
Chebyshev type 1
Chebyshev type 2
Elliptic
G
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
f/f0