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Conference Article

Application of Discriminant Analysis for Signals Identification in Communication Systems

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Abstract

The paper presents noise impact identification over analog and digital signals in the time and frequency domains based on a discriminant analysis. Object of the study are sine, square, triangle and saw tooth waveforms with Uniform White Noise (UWN) and Periodic Random Noise (PRN). Histograms of normal signals distribution are built. The parameters characterizing the probability density functions for untreated and processed signals with FFT - mean value and standard deviation are presented and compared. The results of the analysis of the quality of the generated discriminant linear and quadratic models, presented through the technical approaches as resubstitution and cross-validation, are presented. Quadratic and pseudo-quadratic classifiers have been successfully synthesized to identify untreated signals with UWN and PRN with equal classification precision of 98.80%. Low levels of accuracy are registered for the linear ones compare to the quadratic types of classifiers ranging around 50.00%. Close qualitative indices are achieved with regard to the identification of FFT signals with UWN and PRN, 98.24% for the quadratic and 98.17% for pseudo-quadratic models. The effect of FFT processing is investigated. Positive indications have been identified for increasing classifier accuracy in linear discriminant models within seven, eight percent.

Keywords: noise identification; FFT; normal distribution; discriminant analysis; resubstitution; cross-validation.

1. Introduction

In most studies the Discriminant Analysis (DA) is applied in the fields of the medicine and the communications related to analysis of biomedical and audio signals.

Genetic Linear Discriminant Analysis (GLDA) for reduce size of the dimension of the input vectors and classify of medical data associated with the detection of early-stage diseases was used [1]. LDA classification of electromyographic (EMG) signals based on their selected features is done by a set of metrics - sample entropy (SampEnt), root mean square (RMS), myopulse rate (MYOP) and differential absolute standard deviation value (DASDV) [2]. The analysis supports the work of researchers in the development of computer systems based on the Discrete Wavelet signature analysis of electroencephalogram (EEG) signals for more effective diagnosis of epilepsy, etc. [3].

Fisher Linear Discriminant Analysis (FLDA) in face recognition systems to qualify of audio signals from speakers is embedded [4]. A high efficiency by analyzing of sound waves without White noise is achieved against to the processing of signals with high interference where the accuracy is reduced to 15.00% [5].

Potential applications of DA is associated with the synthesis of signals using correlation characteristics in the electronic circuits, query processing in teletraffic systems, OFDM modulation analysis, etc. [6-8]. In this paper are proposed an innovative application of the Discriminant analysis, Fast Fourier Transformation (FFT) and DA approach in processing and identification of the analog and digital signals with impact of UWN and PRN.

2. Signals and Method

2.1 Simulation and spectral analysis of signals in LabVIEW

For the purpose of the study Sine. Square, Triangle and Sawtooth signals with presence of UWN and PRN were simulated in LabVIEW graphical environment on Fig. 1 and Fig. 2. The signals are simulated in the following parameters – Amplitude =1 and Frequency = 10.1 Hz for waveforms and Noise amplitude/Spectral amplitude = 0.1 when generating of UWN and PRN. After that, a Fourier Spectral Analysis of the signals with superposed noises was applied in a constant FFT size = 1024. The graphical interpretation of the analysis is shown on Fig. 3 and Fig. 4.

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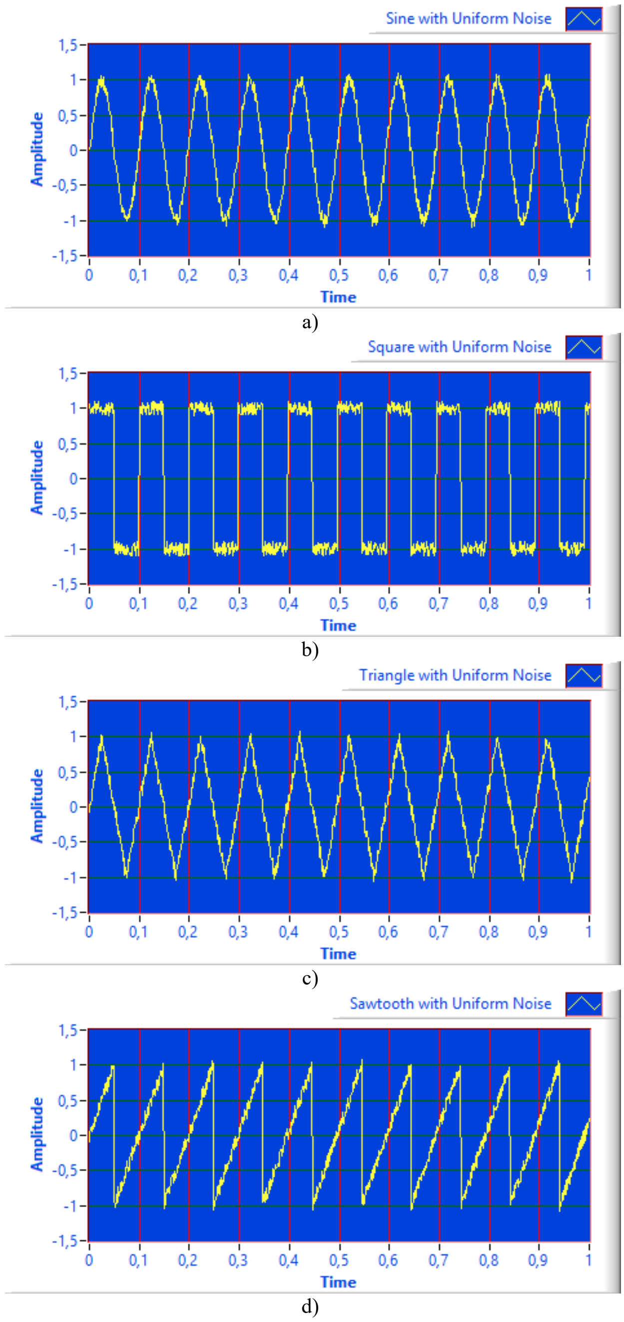


Fig 1. Sine a), Square b), Triangle c) and Sawtooth d) waveforms with UWN.

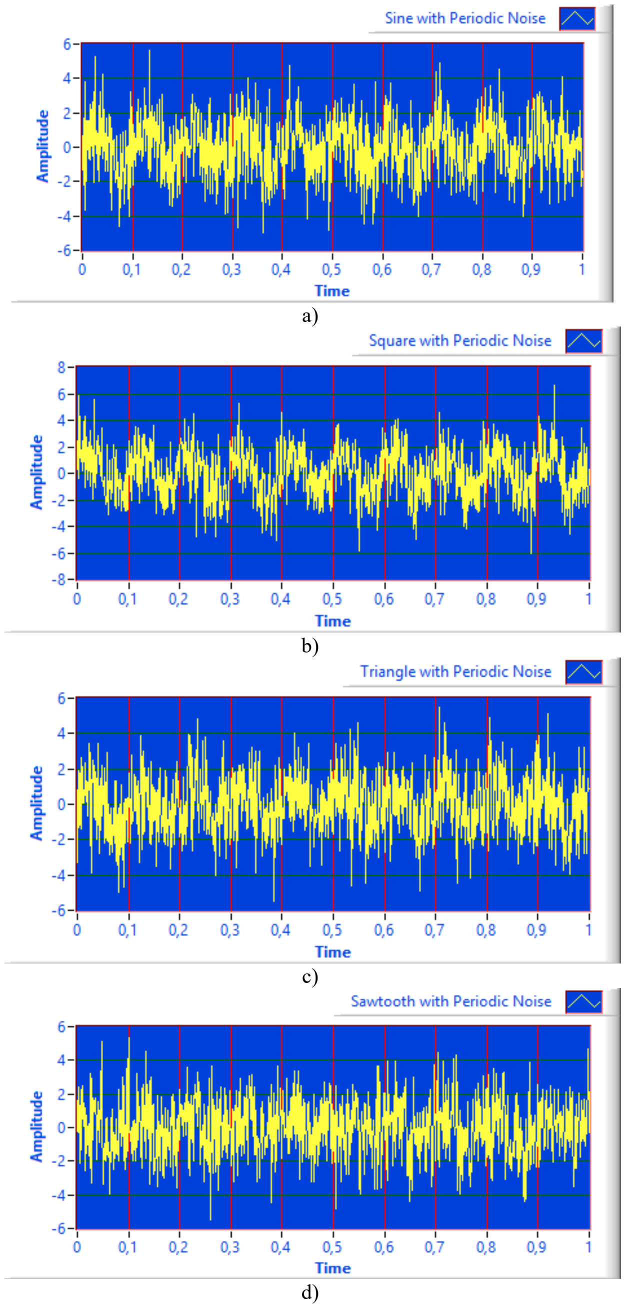


Fig 2. Sine a), Square b), Triangle c) and Sawtooth d) waveforms with PRN.

2.2 Methodical description

In the study are foreseen the following procedures:

- a verification of the correctness of the DA application by Normal (Gaussian) distribution fit at signal processing;
- a creation and synthesis of classification models based on Discriminant analysis in identification of target waveforms in the time and the frequency domains, respectively:
  - ✓ Class №1: Signals with UWN;
  - ✓ Class №2: Signals with PRN;
- a determination the degree of impact on FFT processing over the classification accuracy.

Six types of DA classifiers will be used, respectively denoted by:

- linear;
- diagLinear;
- pseudoLinear;
- quadratic;
- diagQuadratic;
- pseudoQuadratic,

in processing of the target signal groups.

For evaluation of the quality of the Discriminant models the resubstitution and cross-validation techniques will be applied [6-8].

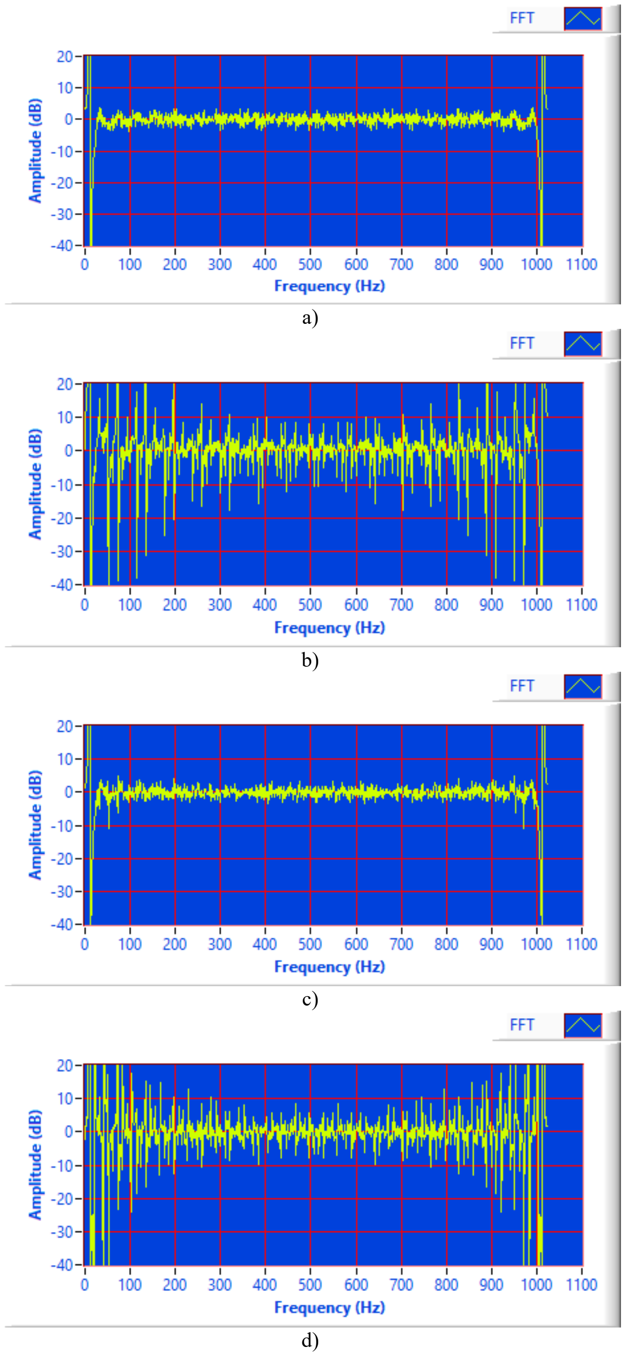


Fig 3. FFT-based analysis of a) Sine, b) Square, c) Triangle and d) Sawtooth waveforms with UWN.

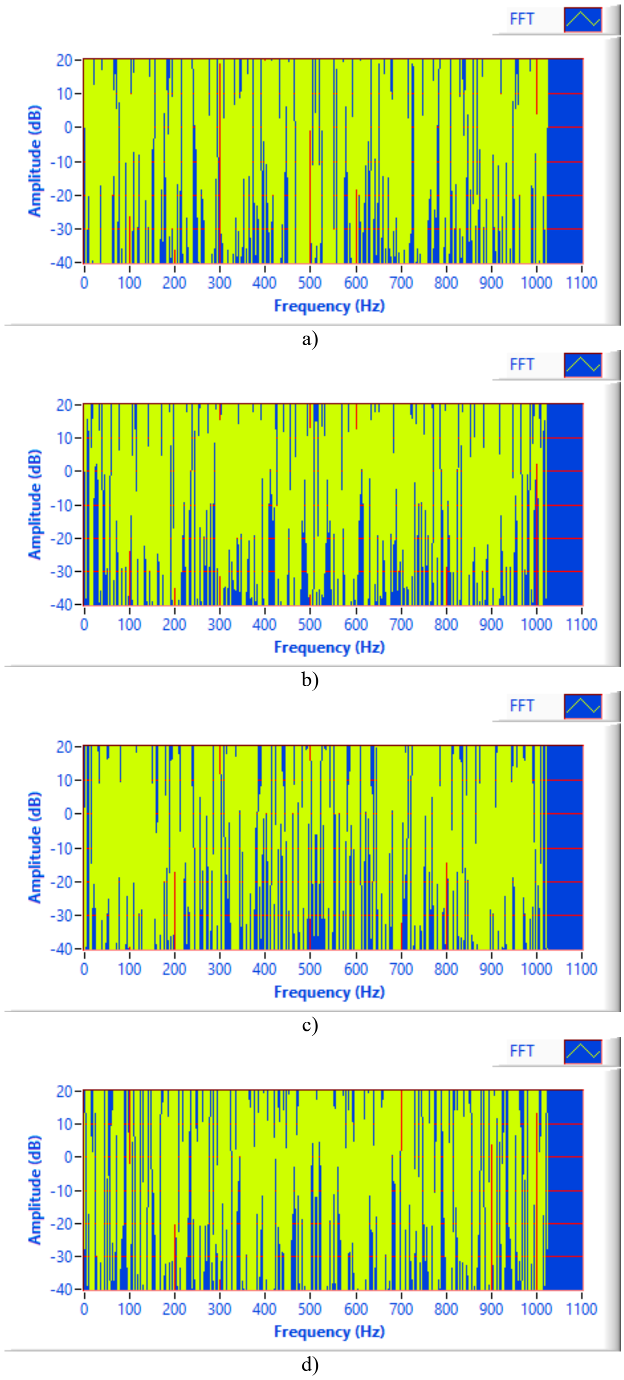


Fig 4. FFT-based analysis of a) Sine, b) Square, c) Triangle and d) Sawtooth waveforms with PRN.

3. Results and discussion

3.1 Normal distribution of signals

Graphs of the probability density functions about the considered variables: Sine, Square, Triangle and Sawtooth with noises are built on Fig. 5. Each variable contains 2000 test samples, respectively 1000 for signals with UWN and 1000 for signals with PRN.

Distribution histograms show approximately good disposition related to the samples for all variables, defined by Gaussian function. The random character of signal curves and the applicability of DA identification models is confirmed.

3.2 Identification of signals with superposed noises without FFT processing

The results about the quality indicators - Error, Accuracy and Misclassifications, with regard to the assessed discriminant classifiers are presented in Table 1. In resubstitution, the lowest accuracy 49.50% is obtained for linear and pseudoLinear types of DA, compared to 46.70% for the diagQuadratic model in k-fold cross-validation. The highest scores 98.80% are registered in quadratic and pseudoQuadratic classifiers, respectively an identical at evaluation by both approaches.

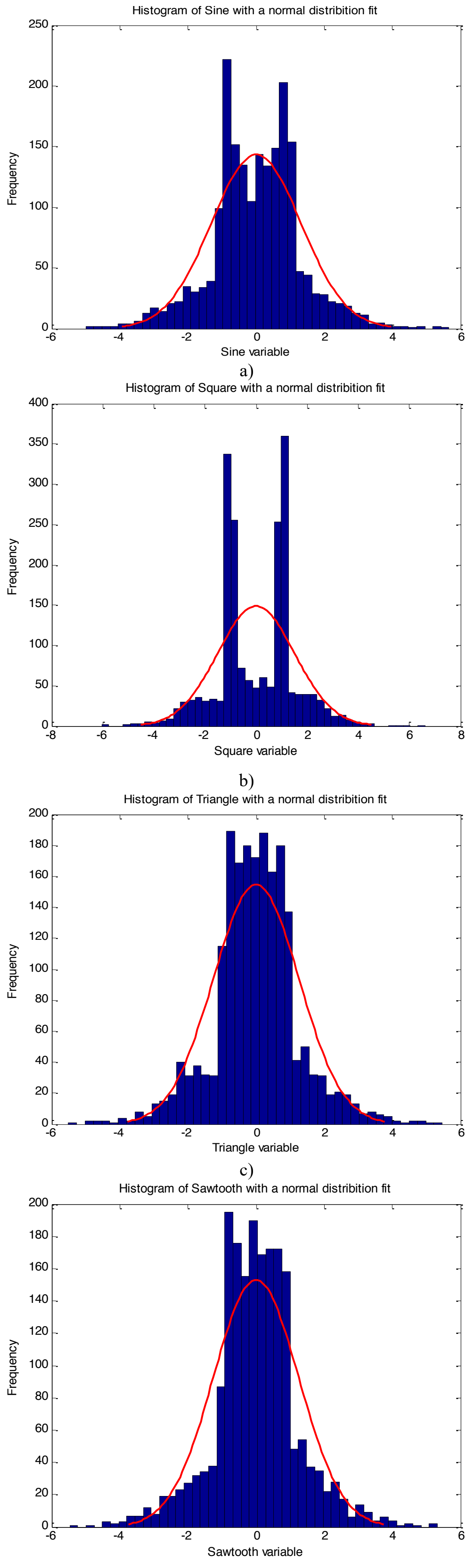


Fig 5. Normal distribution fit of a) Sine, b) Square, c) Triangle and d) Sawtooth variables with noises.

Table 1. Examine the quality of classifiers at identification of signals without FFT processing

Classifier	Error	Accuracy, %	Misclassifications
Resubstitution technique			
linear	0.5050	49.500	1010
diagLinear	0.5020	49.800	1004
pseudoLinear	0.5050	49.500	1010
quadratic	0.0120	**98.800**	24
diagQuadratic	0.0800	92.000	160
pseudoQuadratic	0.0120	**98.800**	24
Cross-validation technique			
linear	0.5181	48.190	1037
diagLinear	0.5330	46.700	1066
pseudoLinear	0.4870	51.300	974
quadratic	0.0120	**98.800**	24
diagQuadratic	0.0800	92.000	160
pseudoQuadratic	0.0120	**98.800**	24
Approximately expected parameters, %			
linear	0.51155	48.845	1023 (1024)
diagLinear	0.51750	48.250	1035
pseudoLinear	0.49600	50.400	992
quadratic	0.01200	***98.800***	24
diagQuadratic	0.08000	92.000	160
pseudoQuadratic	0.01200	***98.800***	24

The approximately expected best accuracy 98.80% for identifying of new data (signal sets do not use for training and test processes of models) is determined. The achieved percentage of success is equally valid in quadratic and pseudo-quadratic models.

Diagrams of the matrices of correct and incorrect classifications as a result of analysis in defining of membership of test signals are given from Fig. 6 to Fig. 8. Coincidences with respect to with regard to the type of matrices are established in:

- linear and pseudoLinear models in resubstitution;
- quadratic and pseudoQuadratic classifiers for both techniques for examine the quality;
- diagQuadratic DA again in the both approaches.

3.3 Identification of signals with superposed noises with FFT processing

An opportunity for adaptation of the discriminant analysis for identification of FFT spectral signals with Uniform White Noise and Periodic Noise has been considered. Table 2 illustrates the results in selecting of models of recognition and classification of noise groups.

A positive effect of Fourier-transformed data which is express in improving the accuracy of linear model to about 7-8% compared to the values of the qualitative parameter in the identification of signals without FFT processing was observed. Regarding to the quadratic type of classifiers, there is a slight decrease in the highest predictive levels in detecting of new signals where would been within 98.17% for pseudoQuadratic and 98.24% for quadratic DAs.

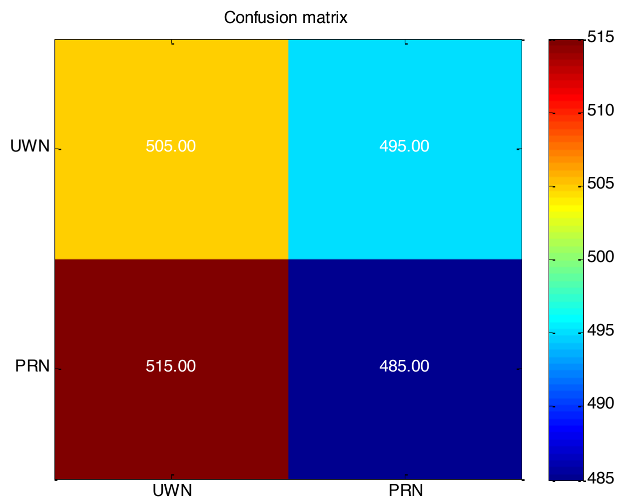
Confusion matrices (Fig. 9 to Fig. 11) to provide information on correct and incorrect distribution of the test sets by output groups were generated. Samples with correct defined membership were obtained, respectively for resubstitution technique:

- 642 from the first and 537 from the second groups in linear and pseudoLinear types;

- 658 from first and 537 from second groups for diagLinear model;
- 994 from the first and 1018 from the second groups for the quadratic and pseudQuadratic classifiers and 998 from the first and 856 from the second groups for the diagQuadratic DA,

with regard to k-fold cross-validation:

- 660 to class №1 and 491 to class №2 in a linear model;
- 635 to class №1 and 508 to class №2 in diagLinear classifier;
- 605 to class №1 and 512 to class №2 in pseudoLinear DA;
- 992 to class №1 and 1020 to class №2 in the quadratic type;
- 995 to class 1 and 854 to class 2 in diagQuadratic model and 992 to class 1 and 1017 to class 2 in pseudoQuadratic classifier.



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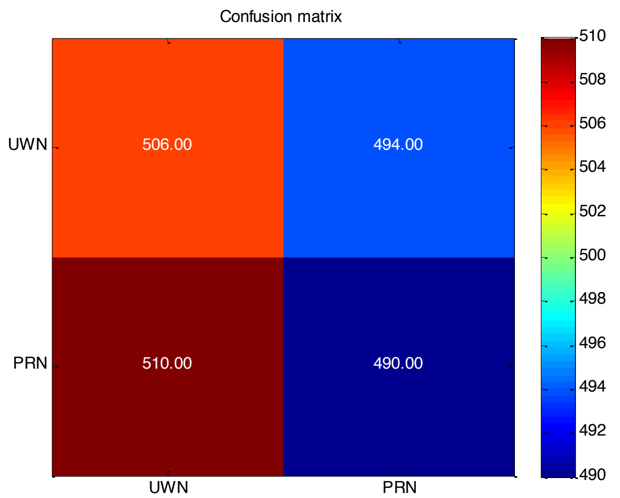
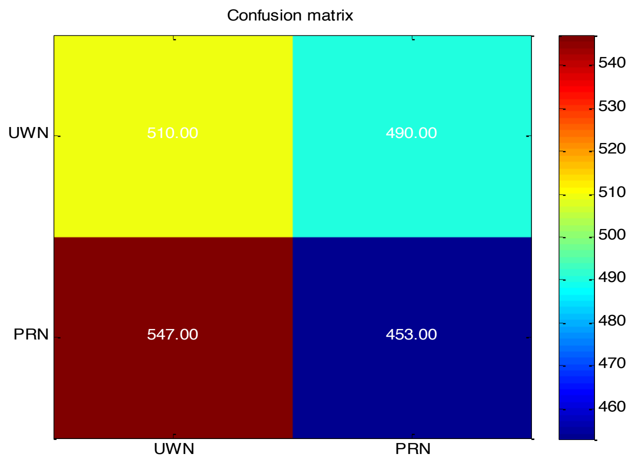


b)

Fig 6. Confusion matrices at Resubstitution for a) linear and pseudoLinear and b) diagLinear classifiers for signals without FFT processing.



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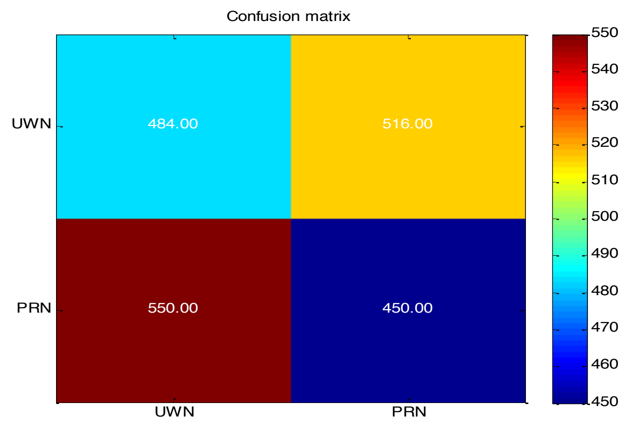

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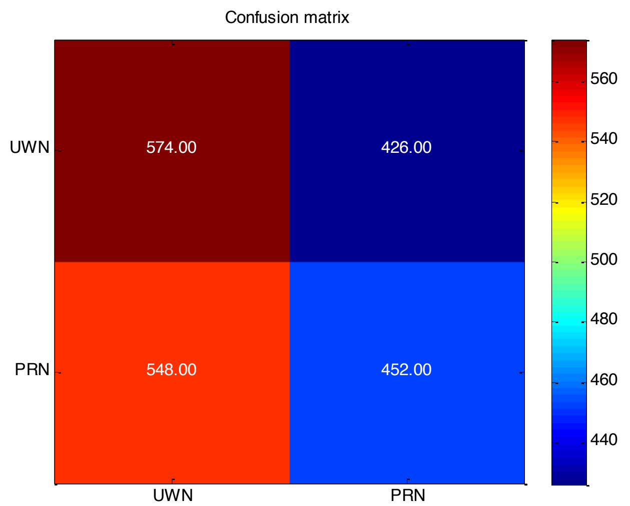
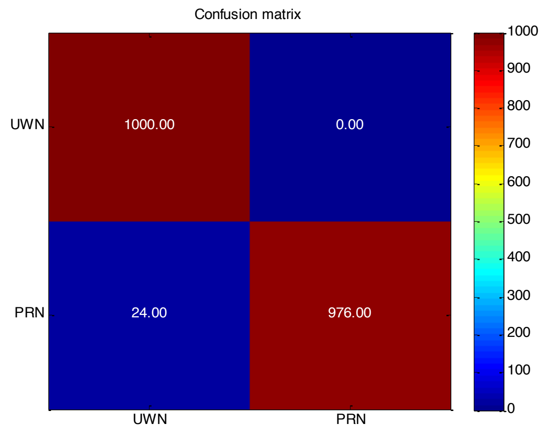


c)

Fig 7. Confusion matrices at Cross-validation for a) linear, b) diagLinear and c) pseudoLinear classifiers for signals without FFT processing.



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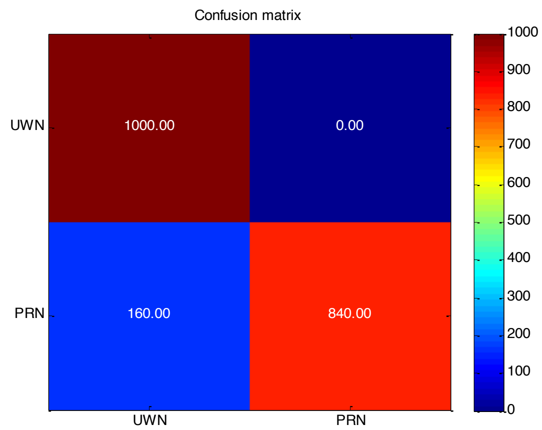
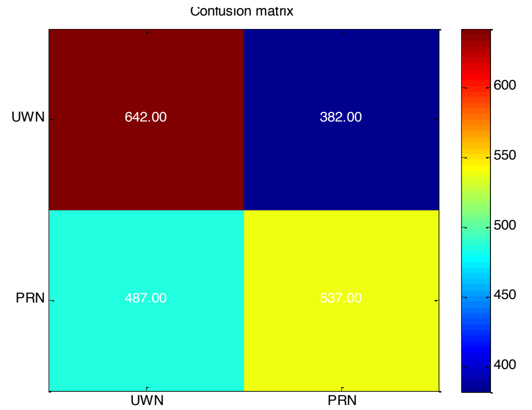


b)

Fig 8. Confusion matrices at Resubstitution and Cross-validation for a) quadratic and pseudoQuadratic and b) diagQuadratic classifiers for signals without FFT processing.

Table 2. Examine the quality of classifiers at identification of signals with FFT processing

Classifier	Error	Accuracy, %	Misclassifications
Resubstitution technique			
linear	0.4243	57.570	869
diagLinear	0.4165	58.350	853
pseudoLinear	0.4243	57.570	869
quadratic	0.0176	**98.240**	36
diagQuadratic	0.0947	90.530	194
pseudoQuadratic	0.0176	**98.240**	36
Cross-validation technique			
linear	0.4380	56.200	897
diagLinear	0.4419	55.810	905
pseudoLinear	0.4546	54.540	931
quadratic	0.0176	**98.240**	36
diagQuadratic	0.0972	90.280	199
pseudoQuadratic	0.0190	98.100	39
Approximately expected parameters, %			
linear	0.43115	56.885	883
diagLinear	0.42920	58.080	879
pseudoLinear	0.43945	56.055	900
quadratic	0.01760	***98.240***	36
diagQuadratic	0.09595	90.405	196 (197)
pseudoQuadratic	0.01830	**98.170**	37 (38)



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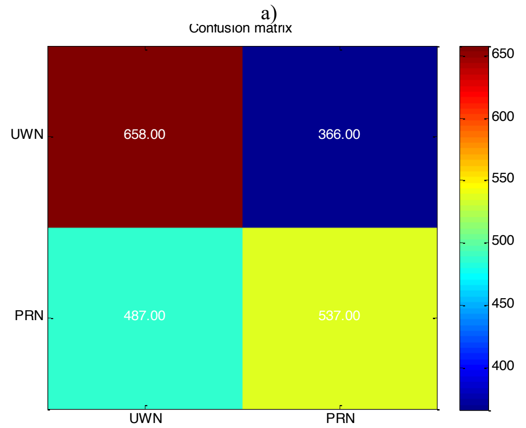
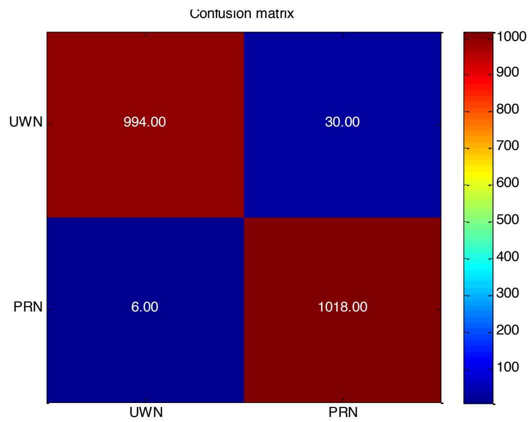


b)

Fig 9. Confusion matrices at Resubstitution for a) linear and pseudoLinear and b) diagLinear classifiers for signals with FFT processing.



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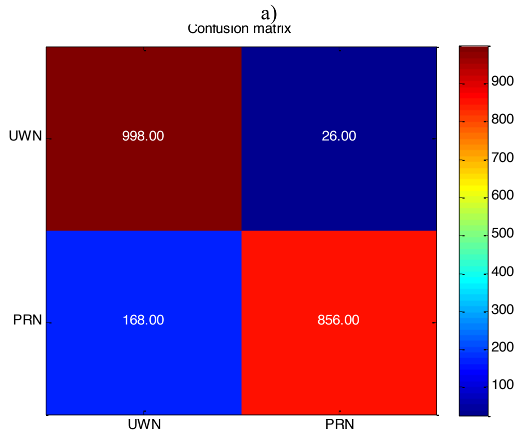
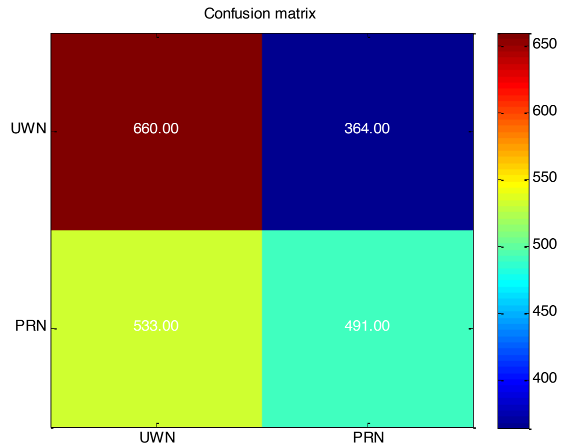


b)

Fig 10. Confusion matrices at Resubstitution for a) quadratic and pseudoQuadratic and b) diagQadratic classifiers for signals with FFT processing.



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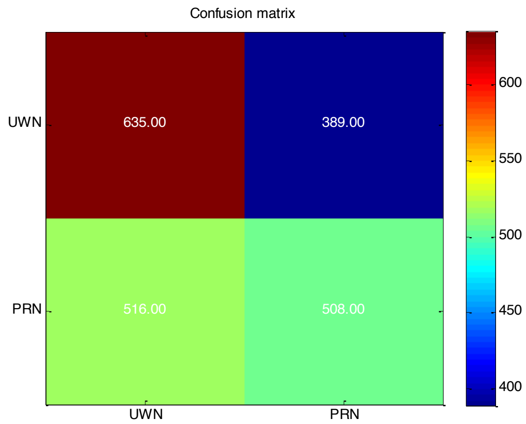

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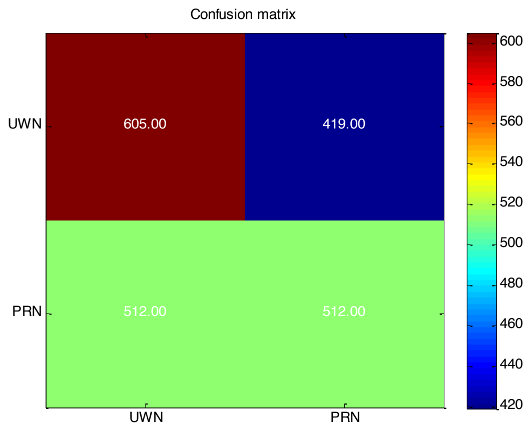

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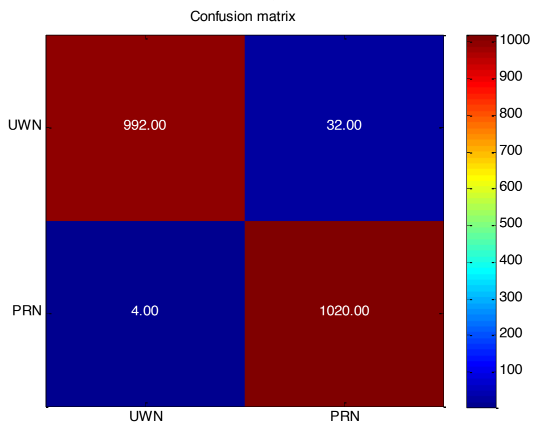
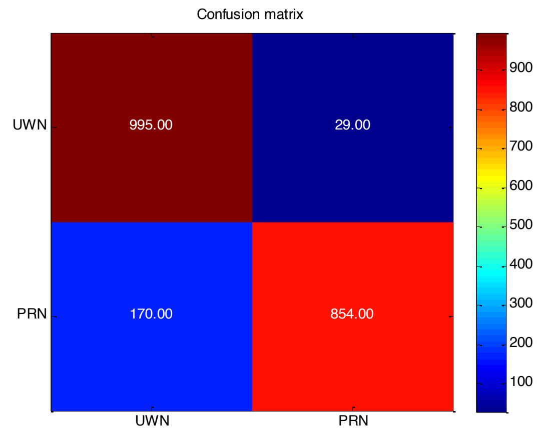
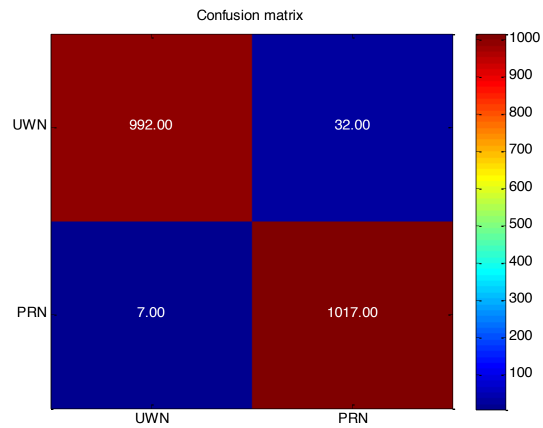


d)



e)



f)

Fig 11. Confusion matrices at Cross-validation for a) linear, b) diagLinear, c) pseudoLinear, d) quadratic, e) diagQuadratic and pseudoQuadratic classifiers for signals with FFT processing.

4. Conclusions

An innovative approach for application of Discriminant analysis to identify of electrical signals with included impact of Uniform and Periodic levels of noise without and with a prior FFT processing is presented.

The high level success rate in recognitions of type of the given signals provides the next steps of research process to increase the number of analyzed noises, testing DA identification of the Wavelet Harmonic Components, etc.

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