Classification of Chaotic Codes using Fuzzy Clustering Techniques and Higher-Order Statistics Features

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Abstract:- In this paper, efficient techniques for the classification of chaotic codes are presented. Four different clustering techniques, namely, k-mean clustering, hierarchical clustering, fuzzy c mean clustering, and subtractive clustering are used for classification. Higher order statistics features obtained from some different types of wavelet transform are utilized. The codes to be classified are assumed to be generated by two different methods. The first method is generating different chaotic codes using different chaotic maps with the same initial values. Two types of chaotic maps are considered, namely the logistic map and bended-up-down map. The second method of code generation is to use the same chaotic map with different initial values.

Keywords— Logistic and Bended-Up-Down Chaotic Codes; Higher Order Statistics; Stationary Wavelet Transform; Non-Decimated Wavelet Transform; Clustering.

1. INTRODUCTION

Chaotic signals have many properties which make them attractive candidate for communications. They have a random-like appearance, they have wideband spectrum, they do not accurately repeat themselves, and they are relatively simple to be implemented. The mathematical definition of chaos is an unpredictable long time behavior arising in a deterministic dynamical system because of the sensitivity to initial conditions. So, these signals are very sensitive to initial conditions and hence one can generate a large number of codes using the same chaotic map. Chaotic codes are used in a variety of applications in communications such as code-division multiple-access (CDMA) [1].

The classification of multi-user chirp modulation signals using higher order moments and cumulants and fuzzy c mean and k means clustering has been considered in additive Gaussian noise channel by the authors in [2] and [3].

Chaotic signal classification using higher order statistics and linear discriminant analysis classifiers was considered in [4].

The paper is organized as follows. Section 2 presents higher order statistics features extraction. Section 3 describes the used clustering techniques and section 4 shows the simulation results. Finally, Section 5 concludes the paper.

2. HIGHER ORDER STATISTICS FEATURES EXTRACTION

Higher order statistics features were obtained using the two eighth order moment and cumulant [4] of the details coefficients of the wavelet transform, stationary wavelet transform, and non-decimated wavelet transform with Daubechies filter and one decomposition level.

3. CLUSTERING TECHNIQUES

In this paper four different clustering techniques have been used. These four clustering techniques are k-mean clustering, fuzzy c mean clustering, and subtractive clustering [5], and hierarchical clustering [6].

4. SIMULATION RESULTS

In this section, the performance, in terms of the probability of correct decision, of the four considered clustering techniques when classifying two codes, one generated from a logistic map and the other generated from a bended-up-down map, with the same initial values 0.3. On the other hand, the two codes are generated from the same logistic map but with different initial values 0.3 and 0.45.

Each signal is chosen to have 150 realizations and 4096 samples (1 second). White Gaussian noise is added to these signals and features are extracted using eight order moment and cumulant as in table 1. In table 2, features are extracted using eight order moment and cumulant from the details coefficient with Daubechies filter and one decomposition level of the discrete wavelet transform, discrete stationary wavelet transform, discrete non-decimated wavelet transform. The two features used are M8 and C8 and are shown in tables 1, 2, 3, and 4 under the constraints of zero mean, unit variance and noise free.

Fig. 1 shows the performance using k-mean clustering technique for two codes generated from two different chaotic maps one generated from a logistic map and the other generated from a bended-up-down map and the same initial values 0.3. Fig. 2 shows the performance using Hierarchical clustering technique for the two codes generated from the two different chaotic maps and the same initial values. Fig. 3 shows the performance using fuzzy c mean clustering technique for also two codes generated from different chaotic maps and the same initial values. From these three figures, we noted that the performance of the features extracted from the non-decimated wavelet transform method outperforms the other methods. Fig. 4shows the performance using subtractive clustering technique for codes generated from different chaotic maps and the same initial values. In this figure, we noted that the performance of the features extracted from the stationary wavelet transform outperforms the other methods.

Fig. 5 shows the performance using k-mean clustering technique for two codes; one generated from a logistic map with initial values 0.3 and the other generated from a logistic map with different initial values 0.45. Fig. 6 shows the performance using Hierarchical clustering technique for the two codes. Fig.7 shows the performance using fuzzy c mean clustering technique for the two codes also. Fig. 8 shows the performance using subtractive clustering technique for the same two codes. From these figures, we noted that the performance of the features extracted from the non-decimated wavelet transform method outperforms the other methods.

Table 1: The eighth order features for codes generated from logistic map with 0.3 and 0.45 initial values and bended-up-down map with 0.3 initial values.

	Logistic map with 0.3 phase	Logistic map with 0.45 phase	Bended up down map with 0.3 phase
M8	1.0025	1.0407	1.0132
C8	-243.8503	-241.6018	-243.2175

Table 2: The eighth order features for details wavelet transform of codes generated from logistic map with 0.3 and 0.45 initial values and bended-up-down map with 0.3 initial values.

	Logistic map with 0.3 phase	Logistic map with 0.45 phase	Bended up down map with 0.3 phase
M8	9.7662	9.9064	13.5019
C8	44.0754	42.6141	102.7349

Table 3: The eighth order features for details stationary wavelet transform of codes generated from logistic map with 0.3 and 0.45 initial values and bended-up-down map with 0.3 initial values.

	Logistic map with 0.3 phase	Logistic map with 0.45 phase	Bended up down map with 0.3 phase
M8	6.7299	10.4772	13.7144
C8	-4.2753	53.8885	105.9743

Table 4: The eighth order features for details non-decimated wavelet transform of codes generated from logistic map with 0.3 and 0.45 initial values and bended-up-down map with 0.3 initial values.

	Logistic map with 0.3 phase	Logistic map with 0.45 phase	Bended up down map with 0.3 phase
M8	9.6065	10.4956	13.7051
C8	41.3795	54.1163	105.8924

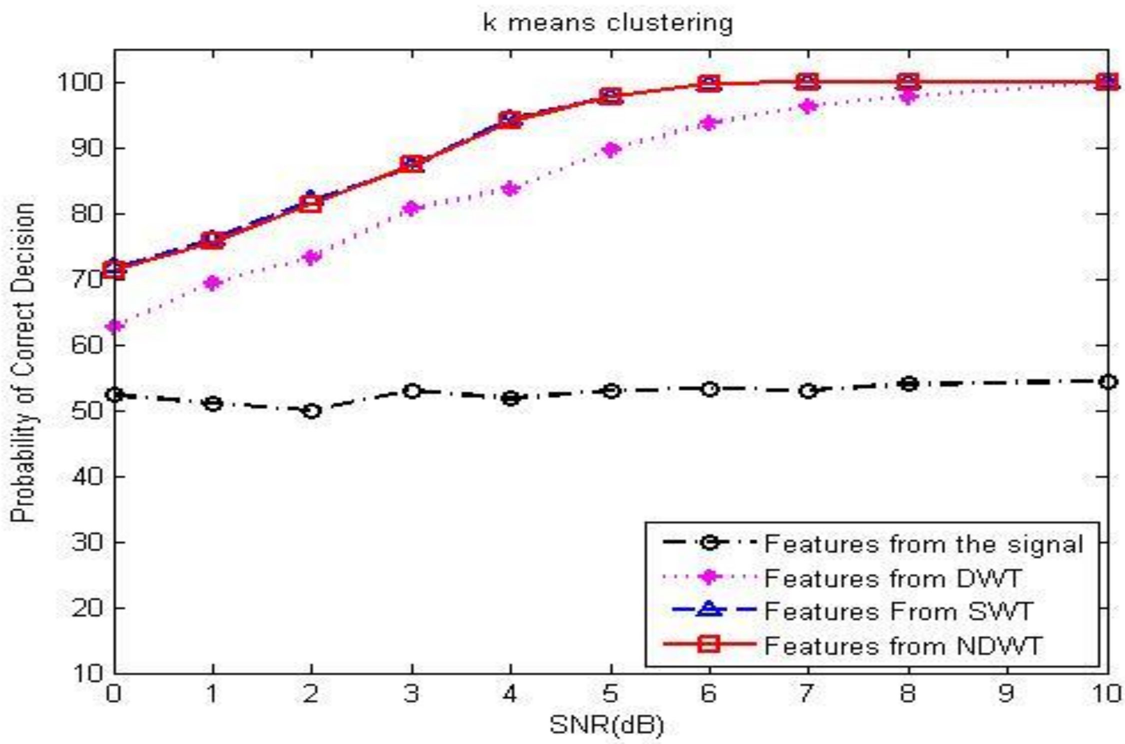

Fig. 1: Performance using k-mean clustering technique for codes generated from different chaotic maps and the same initial values.

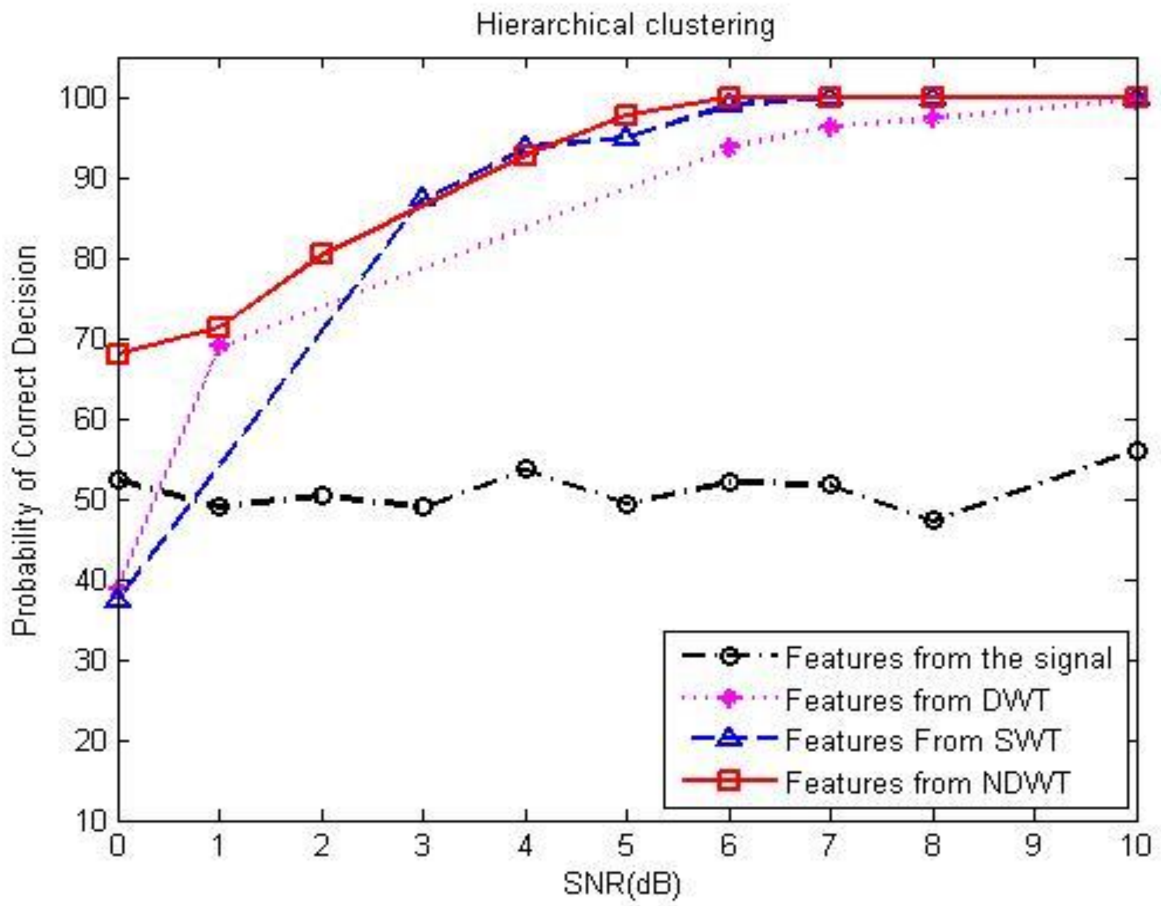

Fig. 2: Performance using Hierarchical clustering technique for codes generated from different chaotic maps and the same initial values.

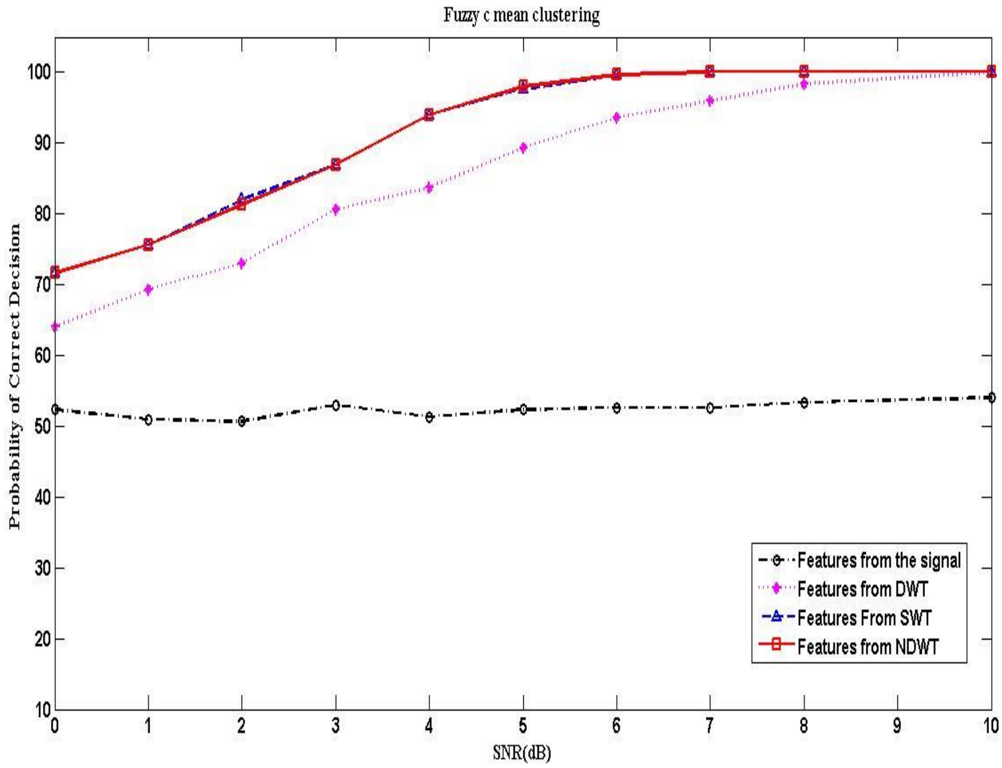

Fig. 3: Performance using Fuzzy c mean clustering technique for codes generated from different chaotic maps and the same initial values.

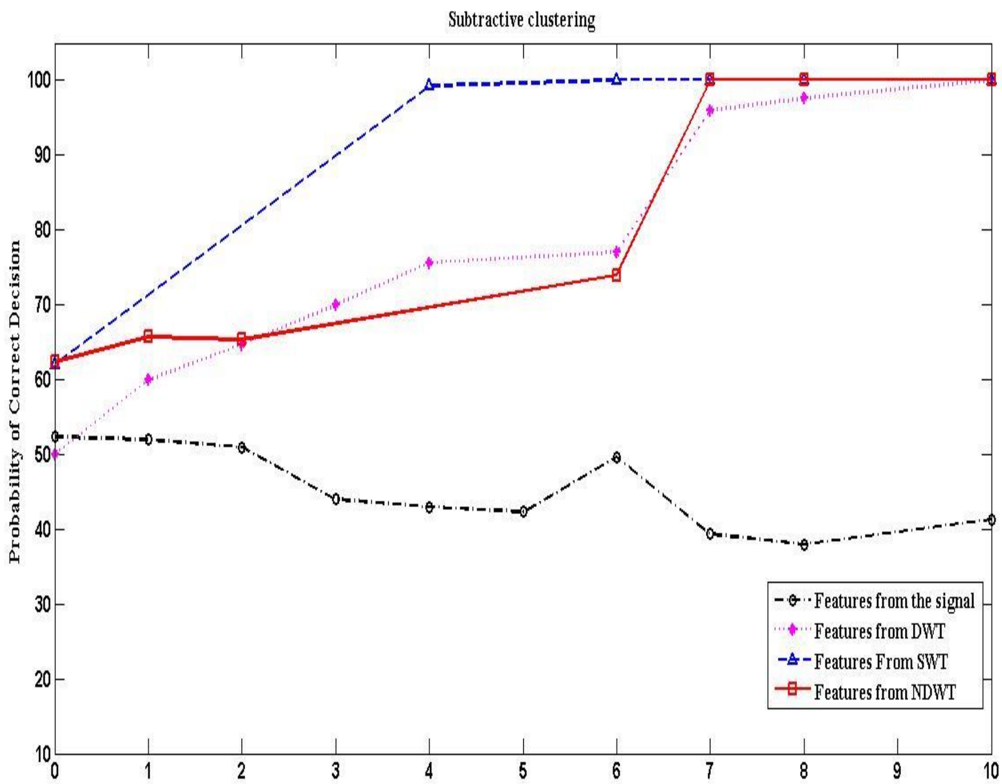

Fig. 4: Performance using Subtractive clustering technique for codes generated from different chaotic maps and the same initial values.

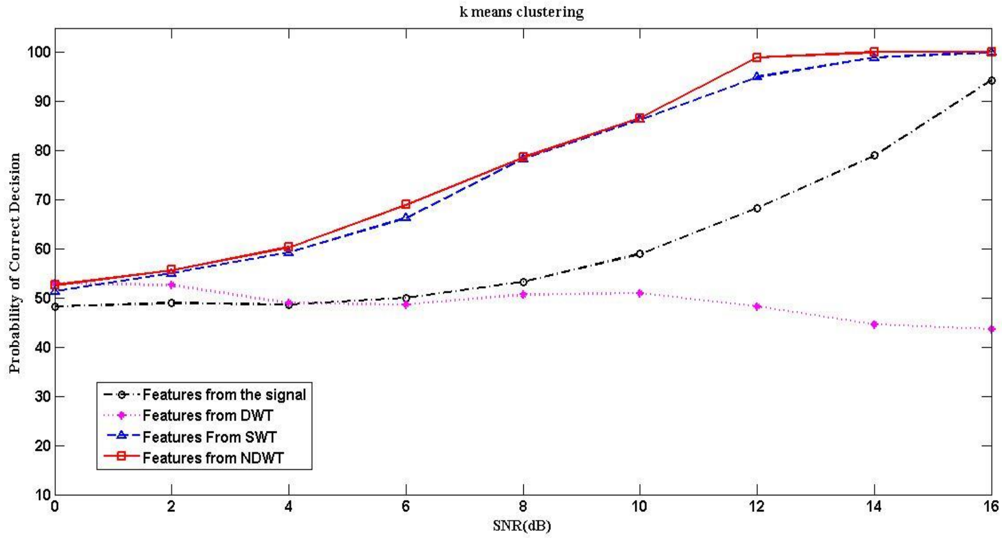

Fig. 5: Performance using k-mean clustering technique for codes generated from same logistic map and the different initial values.

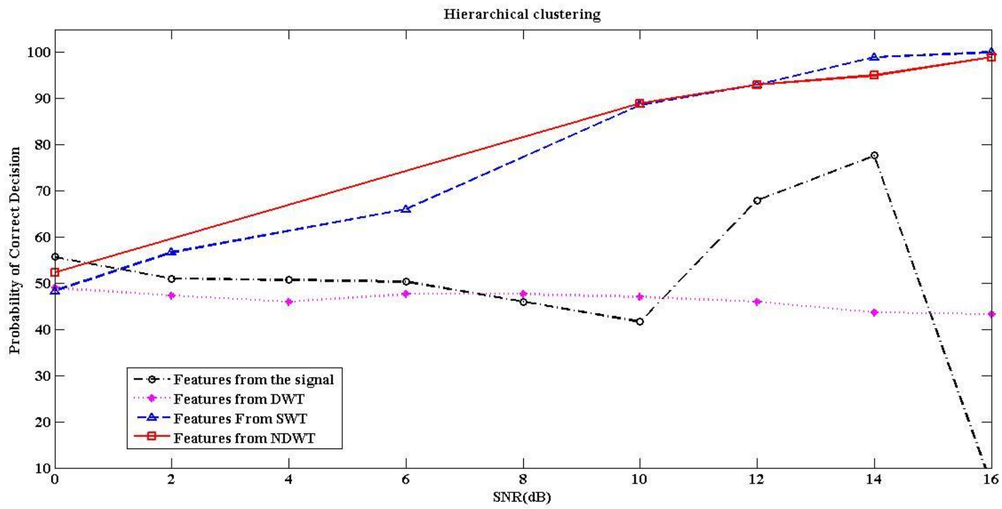

Fig. 6: Performance using Hierarchical clustering technique for codes generated from same logistic map and the different initial values.

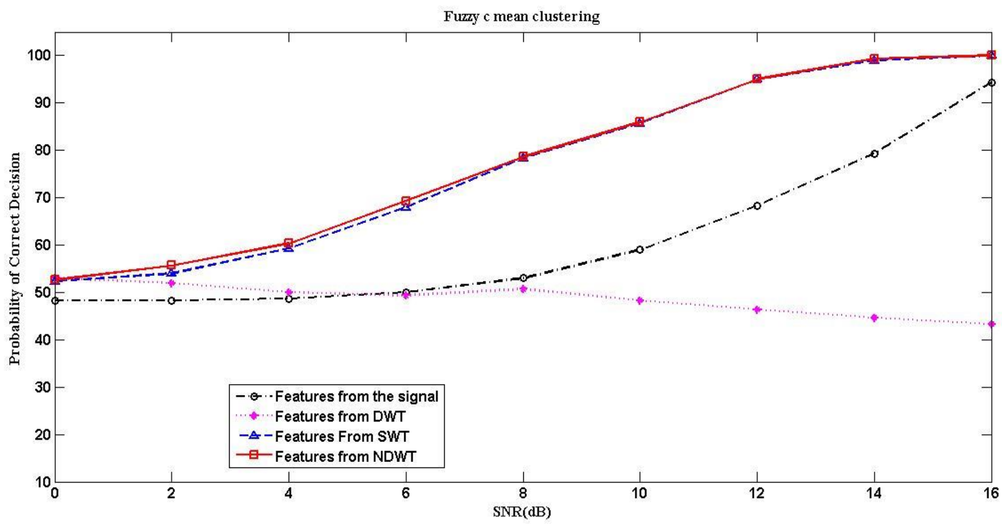

Fig. 7: Performance using Fuzzy c mean clustering technique for codes generated from same logistic map and the different initial values.

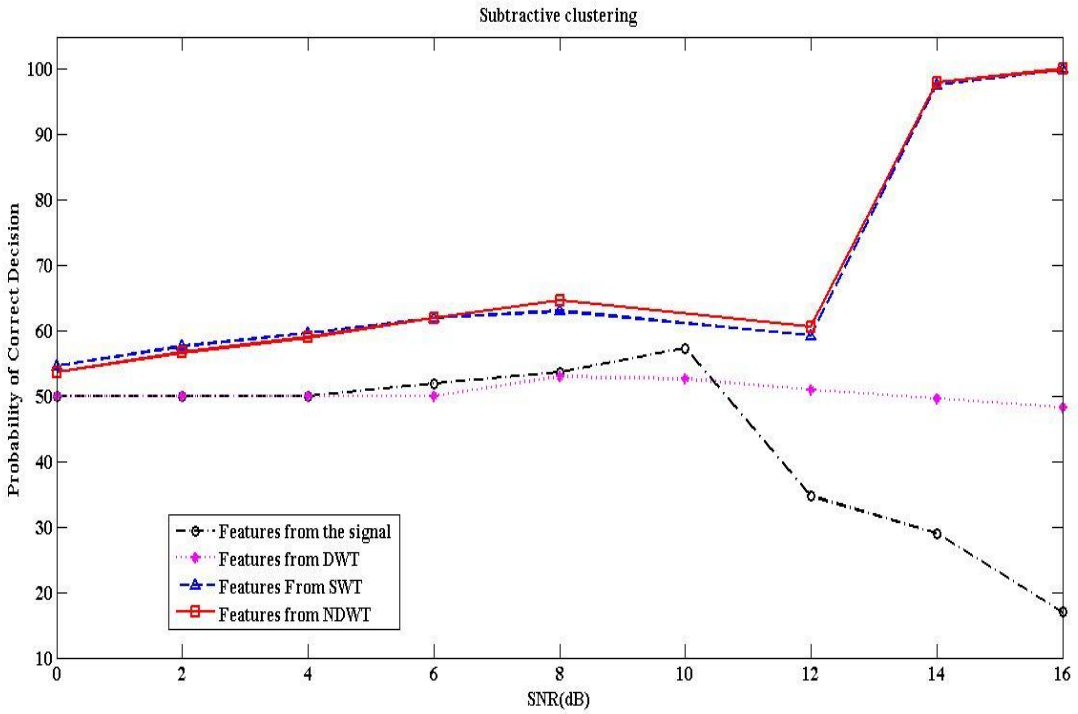

Fig. 8: Performance using Subtractive clustering technique for codes generated from same logistic map and the different initial values.

6. CONCLUSION

Simulation results show that the performance of the features extracted from the non-decimated wavelet transform outperforms the other methods for all results except when using subtractive clustering, for codes generated from different chaotic maps and the same initial values, in which case the stationary wavelet transform outperforms the other methods. Also, the simulation results show that the performance depends on the clustering technique used for classification, the method of features extraction, and the method of generating the chaotic codes.

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