Identifying Degree of Separability in Signal Detection, for Using in Cognitive Radio Approach

Hadi Alipour and Saeed Ayat

***Abstract*—Signal Detection, is a very important issue in cognitive networks. Therefore it is necessary to have a criterion for evaluating the degree of correctness and reliability of the signals. In this paper, we used the separability degree as a criterion for separating and identifying noise from the main signal. This method supposes two states for our signal that are false detection of weak signal, and correct detection of the main signal.**

***Index Terms*—About cognitive radio, correct detection(hit), false alarm, signal detection, degree of separability, threshold.**

I. Introduction

Signal detection has direct application in cognitive radio approach. In other words, second level (unlicensed) users need to recognize the existence of a primary(licensed) user in the network. For example if there is no primary user, then probability distribution function of signal, just will be considered as noise distribution and if a signal has been sent by a primary user, then this function will be a jointly noise and signal distribution together [1]. So, based on a certain and reliable criteria(threshold), secondary user can detect presence or absence of primary user. This has shown in Fig. 1.

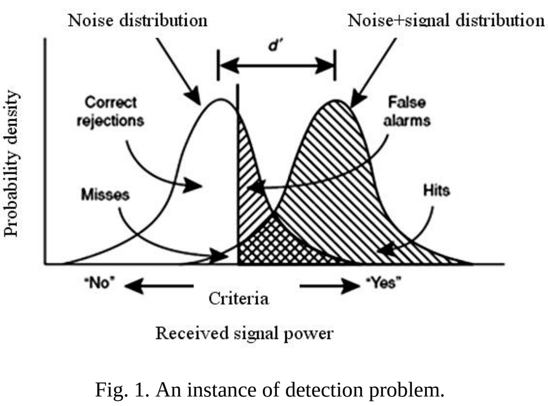

Fig. 1. An instance of detection problem.

Depending on presence or absence of primary user, and decision of secondary user, there are four probabilities. These probabilities have shown in Table I.

So, by sending from primary user, if secondary user detects this signal, we are in "hit" state, else we are in "miss" state from sight of secondary user. In absence of primary user, if secondary user says that there is a signal from primary user, we are in "false alarm" state and otherwise we are in "correct rejection" state from sight of secondary user. It is obvious that the probabilities of mentioned cases depend hardly on a threshold. at the rest of paper, in Section 2 we will explain a classifier model, then in Section 3 the proposed method will be explained. Section 4 involves evaluating the proposed method and Section 5 explains some conclusions about this subject.

TABLE I: Layout of Signal Detection.

	SECONDARY USER SAY "YES"	SECONDARY USER SAY "NO"
Primary user "on"	Hit	Miss
Primary user "off"	False alarm	Correct rejection

Here the problem is as follows. if value of the threshold increases, then hit and false alarm probabilities will be decreased very much, and by decreasing the value of threshold, these values will be increased [2]. Of course, for any valid calculated value for threshold, usually the value calculated for hit will be bigger than that of false alarm. On the other hand, degree of separability(d') depends hardly on mentioned probabilities. we can show the relation between the two more important probabilities(hit and false alarm) in Fig. 2. Having constant probabilities and variable threshold, hit and false alarm will be varied also [3]-[4]. so having the degree of separability (d'), the point that defines relation between mentioned rates(probabilities), moves on the smooth curve and We explain it as "receiver operation curve".

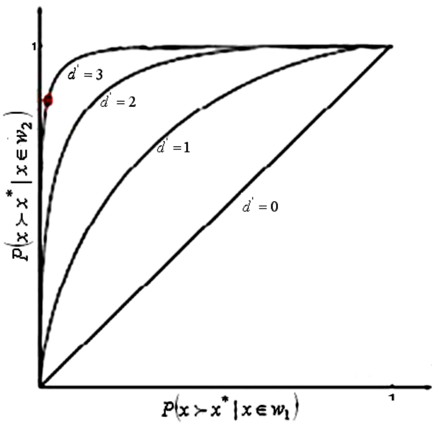

Fig. 2. Receiver operation curve and detection of difrentiability values.

In the above figure, horizontal axis displays probability of mistake(false alarm) based on the (1).

$$P\left(x \succ x^{*} \mid x \in w_{1}\right) \tag{1}$$

and vertical axis displays the probability of correct detection(hit) based on (2).

Manuscript received June 19, 2012; revised August 4, 2012.
Hadi Alipour is with the Payame Noor University, Tehran, Iran (e-mail: Tangehana@gmail.com).
Saeed Ayat was with the sharif Industrial University, Tehran. Iran. He is now with the Department of computer, najaf-abad, Payamr Noor University (e-mail: ayat@ce.sharif.edu).

$$P\left(x \succ x^{*} \mid x \in w_{2}\right) \quad (2)$$

Here, class w_1 explains the probability distributions that are smaller than threshold and say us that there is not some signal. Class w_2 explains the probability distributions that are bigger than the threshold and say us inverse of previous text [4]-[6]. The Binary classifier(that are indeed probability functions) defines the hit and false alarm probabilities as $P\left(x \succ \lambda \mid x \in w_{2}\right)$ and $P\left(x \succ \lambda \mid x \in w_{1}\right)$. By defining the happening rate of this probabilities, respect to a special threshold(here x^*) we can conclude the value of d' (here equal to 3).

Really, in signal detection this graph shows the sensibility curve of binary classifier system respect to the lack of sensibility when the threshold is varied, as Fig. 3.

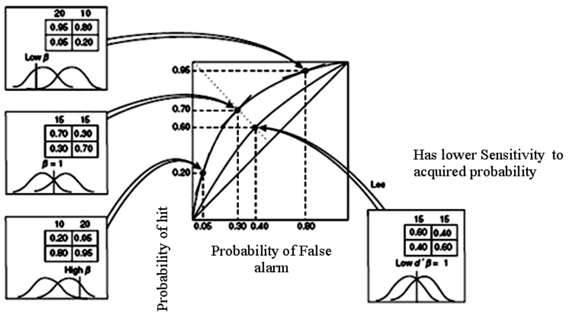

Fig. 3. Analytic graph of ROC and threshold relation.

In this graph, ideal point is the upper-left point of the graph, because probability of hit is 1 and probability of false alarm is 0. The line with angle 45° from lower-left to upper- right points of graph explains the random guesses. Any Used estimator should leads on the top of this line. How much the curve moves toward upper-left point of the graph, we will have better detection, because with equal false alarm probability, this detector will give us better hit probability. So for every detector there is a tradeoff between hit and false alarm probabilities.

II. Identifying the Degree of Separability of Signal and Noise (Proposed Method)

Here, not only we may have a noisy signal, but also we receive the signals from different users of the network. So we try to consider the role of these users in the detection of threshold. Now, if decision threshold equals to λ, we can let it as minimum probability of decision error as $f(\lambda \mid H_1)P_{ON}$ or $f(\lambda \mid H_0)P_{OFF}$. Here, $f(\lambda \mid H_1)$ and $f(\lambda \mid H_0)$ are the probability density functions of received signal from used spectrum and idle spectrum. P_{ON} is the probability of use of the time-interval by primary user and P_{OFF} is the probability that this interval be free.

Indeed, the probability that the spectrum be busy, and the probability of using of it by primary user affect on each other, so the threshold value will not be very little or very big, and eventually, we will not have any problem about hit and false alarm probabilities that be very low or very high. This expression suggests us, to use this method in defining the threshold. Of course, for acquiring better performance in signal detection system, we can pass these signals from a suitable filter and then apply our calculations on it. For example, mach filter and energy detection filter are suitable. Mach filter usually is used when we have primary information about users, and energy detection filter suitable for the situations that we have not any access to the user information. Fig. 4 shows this suggestion [5]-[6].

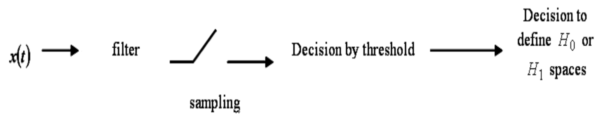

Fig. 4. An applicable approach of spectrum sensing and role of filters in this approach.

Another way to define hit and false alarm probabilities can be shown by (3) and (4).

$$P_d = P\left(\Lambda \succ \lambda \mid H_0\right) \quad (3)$$

$$P_f = P\left(\Lambda \succ \lambda \mid H_1\right) \quad (4)$$

Here, Λ explains the decision statistic, that is compared with threshold and computed by Maximum-Likelihood method [5]-[6]. So we have to identify the threshold so that we can acquire the most values for the ratio of hit-to- false alarm probabilities, because usually there is a tradeoff between them.

III. Evaluating Proposed Method

Here, we let the jointly distribution of noise and main signal(signal+noise) as Gaussian. First we let a special value for distance of two means. Then by testing different threshold values that are lead in a small neighborhood of means, we try to calculate the hit and false alarm probabilities. Then we acquire the ratio of these values and repeat this process for different values of means. Then we select the biggest value of the calculated ratios. This value can help us to define the degree of separability between the noise and the main signal. These values have shown in Table II. The values that are less than 0.5 do not have important role in the detection of false alarm, so we did not apply these values in the computation. Really by using these values we will acquire very big values for the false alarm probability and also will have very little values for hit probability. So the calculation reliability will not be good.

TABLE II: False Alarm Computation.

X \ λ	0.5	0.6	0.7	0.8	0.9	1
0.5	0	0	0	0	0	0
0.6	0.2	0	0	0	0	0
0.7	0.4	0.4	0	0	0	0
0.8	0.6	0.6	0.6	0	0	0
0.9	0.8	0.8	0.8	0.8	0	0
1	1	1	1	1	1	0

Here, x indicates the received signal power and λ is the threshold. After simulation, the results show that the best value for the false alarm is 0.2, that calculated by using the values: $x = 0.5$ and $\lambda = 0.6$. With respect to these values, the value for hit probability will acquire as 0.8(that by considering the value of false alarm, it is suitable). So, because the mean values for noise and mixed signal(noise+signal) in this position have considered as 0 and 4, so the value of degree of separability will computed as 3.5.

IV. Conclusion

This paper, proposed a method for calculating the degree of separability that does not depend on signals properties, and also has considered the role of users in threshold detection. This property suggests us to use this method in cognitive radio approach. Here, we computed a value for threshold that it is not very small and also is not very big, and by this method we calculated values for false alarm and hit probabilities that have not acquired in other methods.

Here, we used degree of separability as a parameter that has important role in separating the main signal from the noise, and we acquired better values for the ratio of hit and false alarm probabilities. This parameter can be considered as criteria for detection of main signal from noise, so that we can become free of problems that related to the statistical analysis of noisy signals.

References

[1] E. Hossain, D. Niyato, and H. Zhu, *Dynamic Spectrum Access and Management in Cognitive Radio Networks*, Cambridge University Press, USA, 2009.

[2] E. Hossain and V. Bhargava, *Cognitive Wireless Communication Networks*, Springer, USA, 2007.

[3] H. Abdi, *Signal Detection Theory (SDT)*, University Of Texas, USA, 2007.

[4] D. Heeger, *Signal Detection Theory*, USA, 1997.

[5] L. Berleman and S. mangold, *Cognitive Radio and Dynamic Spectrum Access*, John Wiley and Sons, USA, 2009.

[6] Y. Xiao and F. Hu, *Cognitive Radio Networks*, CRC Press, USA, 2009.

Hadi Alipour was borned in ghaderabad, shiraz, Iran, on 1977. He graduated with B.S Degree, in Hardware engineering from University of Isfahan, Iran, on 2000. Next, he earned his Master of science Degree in software engineering from Payame Noor University of Tehran, Iran, on March 2011. His major field of study is Neural Network and its applications in signal detection and channel estimation. He is teaching computer science at Payame Noor University of Shiraz, Iran. He has some publications including: 1) "A New Adaptive Statistical-Neural Method for Identifying Non-Linear Transmitter Functions in Radio Channel", *WASET (World Academy of Science Engineering and Technology), France, 2011.* 2) "A Study on Modeling of MIMO Channel by Using Different Neural Network Structures", *WASET (World Academy of Science Engineering and Technology), France, 2011*. His major researches are on Cognitive Radio Approach.