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Stationarity Index for Abrupt Change Detection by the Reassigned Spectrogram

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Abstract: In this study we propose a study of detection of the jumps contained in the non stationary signals, where, we are generally neither aware of the moment of appearance of the change nor of its nature. Various techniques based on the analysis of the non stationary signals on the time frequency plan are used. They are based on the use of the stationarity index which is applied to the spectrogram. In our study we have the importance of the use of another time frequency representation which is the technique of reassigned energies defined by reassigned spectrogram. The developed algorithms were tested on simulated and real non stationary signals. Tthe results obtained are satisfactory.

Key words: Reassigned spectrogram, non stationary signal, stationarity index, speech

INTRODUCTION

In several applications of the signal processing, we generally process signals which are non stationary,but in reality, they are stationary only in short intervals, with sooth or brutal changes or it is non stationary during a smalltime, then it returns to its natural state. Several teams of research throughout the world are interested in the resolution of this type of problem, according to several techniques, the method based on the Time Frequency Representation (TFR) allows the detection of the abrupt spectral changes if a suitable representation of the signal is selected. This technique is based on the calculation of the stationarity index resulting from measurement of the two-dimensional distances; the literature shows that the distance which gives a satisfaction of calculation is the distance of Kolmogorov.

In this study one presents the detection of the brutal changes of the spectrum by using the stationarity index. The later is derived from both the spectrogram and the reassigned spectrogram .We improve the contribution of detection by using the representation of concentrated energies.

Spectrogram and reassigned spectrogram: The short time Fourier transform F_x of signal x is defined by the Eq.[1]

$$F_x(t,v;h) = \int x(u).h^*(u-t).\exp(-j.2.\pi.v.u)du \qquad (1)$$

where h(t) is short time analysis window localized around t = 0 and v = 0. If we consider the square modulus of F_X we obtain the spectral concentration of energy of the signal windowed by h which is x (u).h*(t-u).

The equation representing the spectrogram of signal x is[1,2]

$$S_x(t,v;h) = \left|F_x(t,v;h)\right|^2 \qquad (2)$$

It is noted that the spectrogram is nonnegative from where the possibility of the application of the distances used in density probability measurements, the density is generally standardized. The density of total energy is given by:

$$\iint S_x(t,v;h)dtdv = E_x \qquad (3)$$

E_X: represent the energy of the signal x in the time frequency plan.

The properties of the spectrogram include the variability in time and in frequency, although it is applied for show spectral variation signals, a compromise exists between the temporal and the spectral resolution, the increase in the temporal resolution reduced the spectral resolution and vice versa.

As it is regarded as a bilinear representation, the problem of interference between adjacent spectral components arises, but for rather distant spectral components this phenomenon is reduced

In order to avoid the spectral overlapping of the adjacent components, the method of reassigned energy in the time frequency plan reduces more this problem of interference and for a nonnegative spectral representation the reassigned spectrogram meets our need, it consists in giving a better concentration of energy in the time frequency plan, it reduces more the problem of interferences between spectral components that are rather near.

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In this study the information of the phase of the short time Fourier transform is used to reassign the distribution of energy which is far from the point of sampling (t,v) but at the same time in the centre of gravity of energy balanced by the window h into $(\hat{t},\hat{v})$ such as:

$$\hat{t} = t - \Re\left\{\frac{F_x(t,v;\tau_h).F_x^*(t,v,h)}{|F_x(t,v;h)|^2}\right\} \quad (4)$$

$$\hat{v} = v + \Im\left\{\frac{F_x(t,v;D_h).F_x^*(t,v;h)}{2\pi|F_x(t,v;h)|^2}\right\} \quad (5)$$

where $\Re$ and $\Im$ are respectively the real part and the imaginary part of the ratios in (4) and (5) with $\tau_h = t.h(t)$ and $D_h(t) = \frac{dh}{dt}(t)$

The general form of the reassigned spectrogram is given by[3,4]

$$S_x^r(t',v';h) = \iint S_x(t,v;h).\delta(t' - \hat{t}(x;t,v)).\delta(v' - \hat{v}(x;t,v))dt.dv \quad (6)$$

The stationarity index and distances measurements.

To compare the similarity between two TFR, many authors have quite simply chosen the Euclidean distance, deduced from Lq distances given by::

$$dL_q(TFR_{x1}^{\phi}, TFR_{x2}^{\phi}) = \left[\iint |TFR_{x1}^{\phi}(t,f) - TFR_{x2}^{\phi}(t,f)|^q dt.df\right]^{\frac{1}{q}} \quad (7)$$

Such that TFR_x^{Φ}: Indicate the time frequency representation of signal x of kernel Φ, one can particularize these distances by the value of q.

- q = 1: mean absolute distance or Manhatten Kolmogorov distance.
- q = 2: mean quadratic distance or Euclidean distance
- q → 8: maximal deviation

The distance between law of probability P (a, b) defines in a nonnegative field D, such as:

$$\forall(a,b) \in D \ \ P(a,b) \geq 0 \quad (8)$$

$$\int P(a,b) \geq 0 \quad (9)$$

other distances have summers quoted in[4,5] like that of Kullback, Chernoff and Matusita, the distance chosen in our study is that of Kolmogorov defined previously, it was shown that is the best distance applied in work of[6] in the detection of the brutal changes by using the stationarity index which corresponds to it.

The principle of this technique of detection is based on the measure of distance between two sub-images selected from a total image of the time frequency representation of the studied signal, at every moment two sub-images $I_1(t, \tau, f)$ and $I_2(t, \tau, f)$ are extracted from this representation and of each with dimensions :

$$I_1(t,\tau,f) = TFR_x(t - p + \tau, f) \quad (10)$$

$$I_2(t,\tau,f) = TFR_x(t + \tau, f) \quad (11)$$

Such that: TFR_x: Time frequency representation of signal x, p indicate temporal width of sub-image and $\tau \in [0, p]$, the parameter p is significant in the selectivity and the sensitivity of detection, if one wants to measure the brutal change of the spectral components of the non stationary signal of well limited duration, then the choice of the value of p is taken into account of this limit.

The stationarity index indicate in this measurement and determine the instant of the brutal change of the signal spectrum, if a change occurs, one notes a peak on this index, on the contrary, the index of stationarity converges towards zero.

We define this index[6] by:

$$SI(t) = \int_{\tau=0}^{p} \int \left| |NI_1(t,\tau,f)| - |NI_2(t,\tau,f)| \right| dt.df \quad (12)$$

and

$$NI(t,\tau,f) = \frac{|I(t,\tau,f)|}{\iint |I(t,\tau,f)| dt.df} \quad (13)$$

The standardization of the energy spectral density makes it possible to consider theses sub-images densities of probabilities, since the spectrogram and the reassigned spectrogram are defined nonnegative, then the method of detection by the stationarity index finds its application valid.

Study and simulations: In our simulation we propose a signal test and three words of speech in the three languages, in English hello, French bonjour and in Arabic salam .

Synthetic signal: We present a signal of 512 samples and four sinusoidal spectral components of standardized frequencies, the sampling rate is 1 kHz, the four components of the signal are: si(f, [|ton, toff]), and which presents three spectral changes at the instants (179 to180), (209 to 210), (239 to 240); s1(0.2;[1:179]); s2(0.25, [180, 209]); s3(0.3, [210, 239]); s4(0.2;[240,512]).

Table 1: Abrupt spectral change time instants of test signal without noise

Value of p	3		7		11		21		31	
TFR										
]Mean time	sp	rsp	sp	rsp	sp	rsp	sp	rsp	sp	rsp
T1	180	180	180	180	180	180	180	179	180	178
T2	210	210	210	209	210	211	211	209	X	209
T3	240	240	240	240	240	239	240	241	242	243

Table(2): abrupt spectral change time instant of noisy test signal

Value of p	3		7		11		21		31	
TFR										
Mean time	sp	rsp	sp	ssp	sp	rsp	sp	rsp	sp	rsp
T1	180	179	180	179	180	180	180	180	178	178
T2	210	211	210	210	213	211	211	209	X	209
T3	241	239	241	241	241	240	241	241	244	243

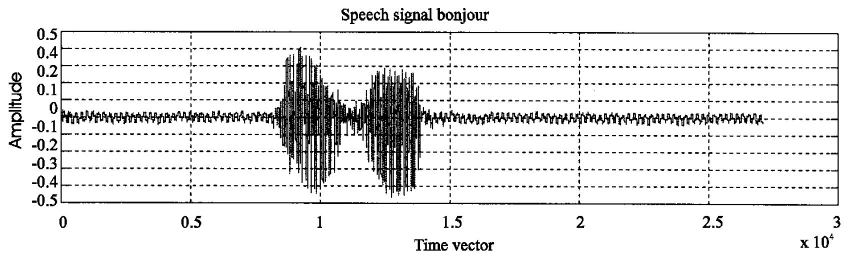

Fig. 1a: Speech signal bonjour

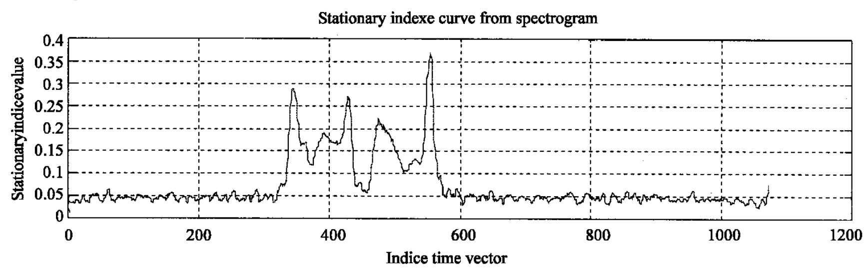

Fig. 1b : Stationarity index derived from spectrogram

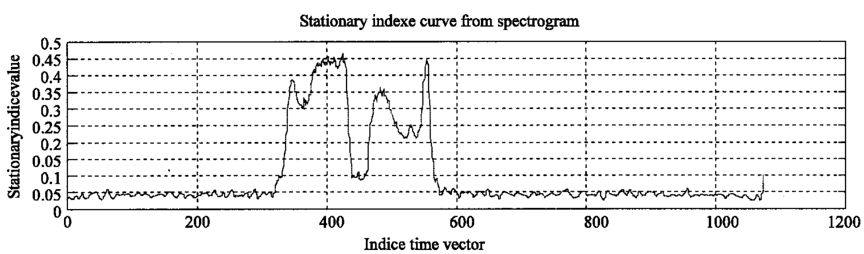

Fig. 1c: Stationarity index derived from reassigned spectrogram

we present in Table 1 the result of the detection of the signal test non disturbed by application of the stationarity index by using like time frequency representation TFR the spectrogram sp and the reassigned spectrogram rsp for different value from p from sub-images of the TFR, in Table 2, the result for the same one is applied to the synthetic signal but imerged in a noise of 10 dB.

X: masked instant not detected: we note that the increase in the width p of sub-image masks the spectral changes of short duration, which one can conclude that the duration of p must be to the maximum half of the small spectral component of the signal which one wants to detect its variation and especially for the study of the spectrogram.

Speech signal: the speech words which have summers selected for this application are bonjour, hello and salam . the frequency of sampling is Fs=11025 Hz, the represent, respectively the signal of the word bonjour, the stationarity index of the spectrogram, and that of the reassigned spectrogram, even representation of the words hello and salam are into Fig. 1-3. Figure 4

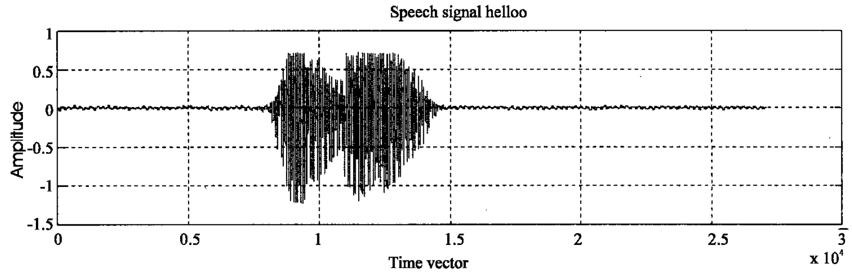

Fig. 2a: Speech signal hello

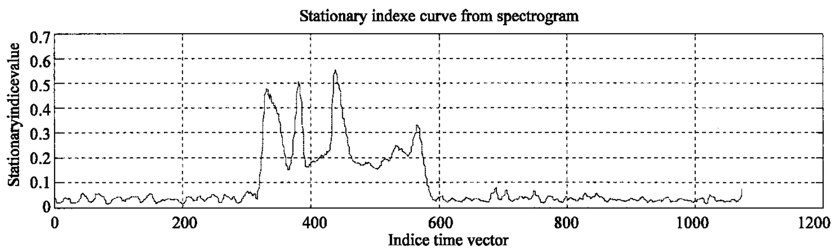

Fig. 2b: Stationarity index derived from spectrogram

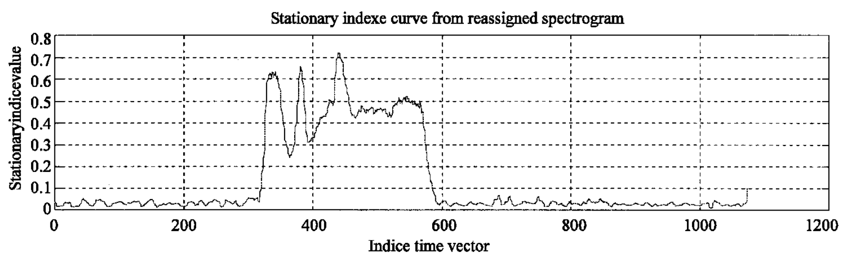

Fig. 2c: Stationarity index derived from reassigned spectrogram

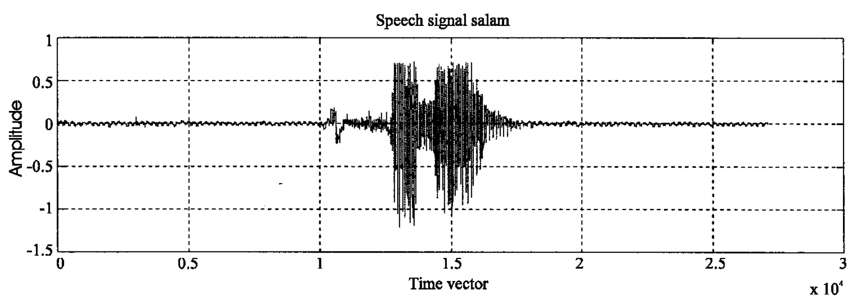

Fig. 3a: Speech signal Salam

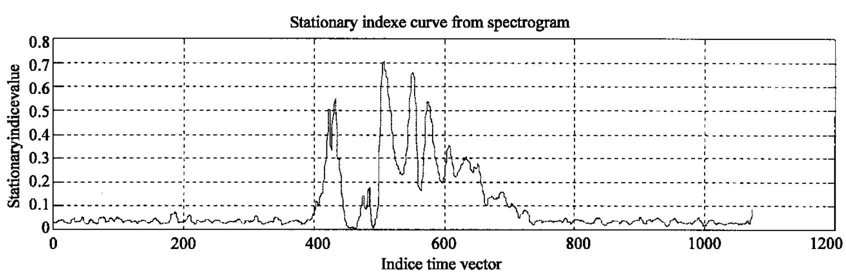

Fig. 3b: Stationarity index derived from spectrogram

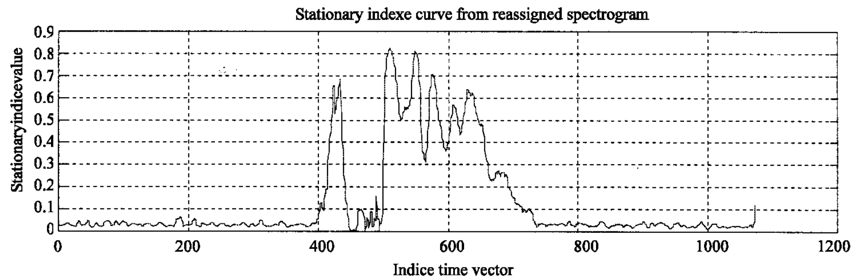

Fig. 3c: Stationarity index derived from reassigned spectrogram

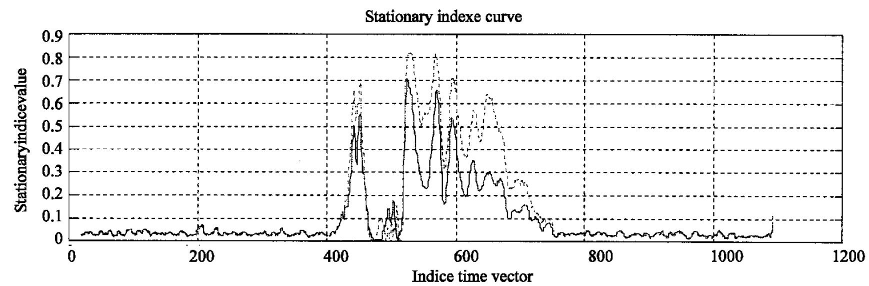

Fig. 4: Stationarity index from spectrogram solid curve, from reassigned spectrogramdotted curve of speech signal salam

the same stationarity index of the same word salam with the same duration p. The choice of the duration of the window of analysis h of the spectrogram was selected for duration of 18.2 ms, with an overlapping of 87.5 %. The choice of the duration of p must be limited at least by the maximum duration of the window h, for our application we have choosen a duration of p equal 22.8 ms.

CONCLUSION

This study has the importance of the use of the transformation reassigned spectrogram for the detection of the abrupt changes of the spectrum of the non stationary signal, the stationarity index derived from the reassigned spectrogram presents a larger slope and an apparent peak compared with the results drawn from the stationarity index derived from the simple spectrogram.

The overlapping greater than 75% of the window of the spectrogram is significant in detection. Finally the choice of the width of sub-image of measurement of distance in the time frequency plan, is with the choice of the detection of the small spectral component of the signal which marks the abrupt change, more this width is weak, more the detection of the weak variations will be detected.

REFERENCES

1. Allen, J. and L. Rabiner, 1997. A Unified Approach to Short-Time Fourier Analysis and synthesis proc of the IEEE, pp: 1558-64.
2. Nawab, S. and T. Quatieri, 1988. Short-time fourier transform, chapter in advanced topics in signal processing J. Lim and A. Oppenheim Eds, prentice hall, Englewood Cliffs, NJ.
3. Auger, F. and P. Flandrin, 1995. Improving the readability of time-frequency and time scale Représentation by The Reassignment Method IEEE transactions on signal processing, pp: 1068-89.
4. Basseville, M., 1989. Distance measure for signal processing and pattern recognition, signal processing, pp: 349-369.
5. Selin Aviyente, 2004. Information processing on the time frequency plane, IEEE, ICASSP.
6. Laurent, H. and C. Doncarli, 1998. Stationarity index for abrupt change detection in the time-frequency plane, IEEESP Letters.