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AN EVALUATION OF NOISE EFFECT IN PITCH DETERMINATION: USE OF MULTIRESOLUTION ANALYSIS TO IMPROVE THE RESULTS

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1. INTRODUCTION

The purpose of this work was to study the noise effect at the time of evaluate the pitch with several algorithms. Various signals were analyzed at different noise levels. In general medium and high noise presence suppose the bad determination of pitch in the algorithms used.

Last decade the wavelet analysis was developed intensely. Several applications were appeared in image processing and time-frequency analysis. An example was a method to pitch determination using wavelet transform in the time-domain and frequency-domain [7]. Our last aim was to improve pitch determination doing use of multiresolution analysis previously to use the algorithms of pitch extraction.

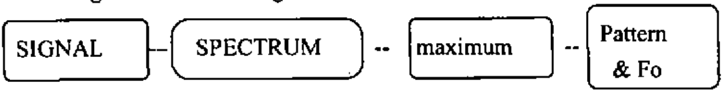
2. PITCH DETERMINATION ALGORITHMS

FFT method.

This method was used by Hiraoka et al [2]. A direct study of spectrum is realized into (95,500) Hz interval. The block diagram resume the algorithm:

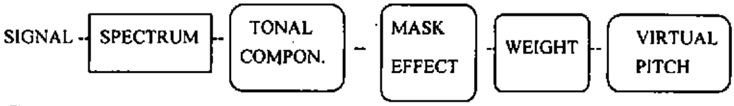
Goldstein's model.

Duifhuis et al.[1] implementation of Goldstein's model was used. The block diagram resume the algorithm:



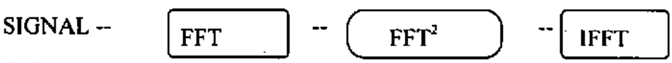
Terhardt's algorithm.

Terhardt et al algorithm [5] was used. The block diagram resume the algorithm:



Cestrum.

Autocorrelation method was used [3]. The block diagram resume the algorithm:



Autopitch.

This method evaluate the pitch looking for a periodicity pattern in time-domain. A temporal interval is fixed and its periodicity in signal is evaluated comparing the interval with all intervals of the same duration present in signal. The interval more repeated is selected as the inverse of the pitch of the signal.

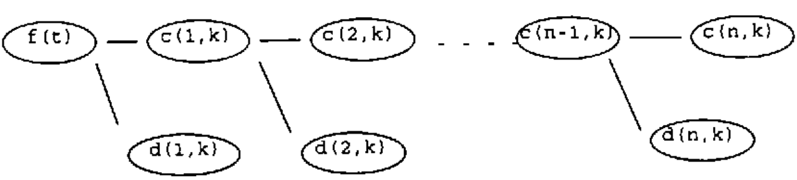
3. MULTIRESOLUTION ANALYSIS

The dyadic wavelet transform (DWT), is defined as:

$$WTy(1/2j, k/2j) = \int y(x)\, \{2^{j/2} f^*(2^j - k)\}\, dx$$

where f is the mother wavelet. The algorithm of multiresolution analysis (MRA), is used to compute this coefficients. The algorithm produce in each step two signals:

1. The coefficients of DWT for a fixed j.
2. An approximation to the original signal.



BLOCK DIAGRAM OF MULTIRESOLUTION ANALYSIS

10-Daubechies's coefficients were used to compute consecutive signal approximations.

4. EXPERIMENT

Method.

To observe the noise effect in the algoritnms, several spanish vowels were analyzed. Samples were elaborated by 16-bits Sound Blaster. A C.D. edited by U.N.E.D [8], was used as record source. Sample format was 8-bits, MONO, 11025 Hz sample frequency. Examples studied were: E1. vowel /o/ in spanish word "donde" (51 dB); E2. vowel /i/ in spanish word "tinte" (55 dB); E3. vowel /a/ in spanish word "al" (46 dB); E4. vowel /u/ in spanish word "usen" (58 dB); E5. vowel /o/ in spanish word "noche" (57 dB).

First, original signals without noise were analyzed. Successively low-pass white noise was mixed with original signals at differents noise levels (40 dB, 45 dB, 50 dB, 55 dB, 60 dB). Algorithms were applicated at each noise level observing new pitch values.

When noise presence involve different pitch values from pitch values of signal without noise, multiresolution analysis was used to obtain consecutive approximations to the original signal. This algorithm was used with 10-Daubechies's coefficients [7]. In each MRA approximation level pitch algorithms, that produce different pitch values, were again applicated. New pitch value was observed in each approximation level.

To evaluate noise presence effect at the time to calculate the pitch, a coefficient C.F was introduced. This coefficient measure the pitch deviation in presence of noise with reference to the picth of signal original without noise.

$$C.F = N^{-1} \sum_{n=1,N} |1 - f(n) / f(i)|$$

f(n) noise presence pitch .
f(i) initial pitch .
N number of examples.

This coefficient measure exclusively the mean distance of noisy pitch to original pitch. Obviously $C.F \geq 0$, and $C.F = 0$ when the noisy picth is the same that the original pitch.

Results.

Values of coefficient C.F. obtained are showed in Fig 1(a). In general, the coefficient C.F. increase as noise level increase. After noise effect in the algorithms was observed, the improve that MRA use produce at the time of calculate the pitch was studied. Again the coefficient C.F was studied. New values of C.F coefficient are showed in Fig 1(b).

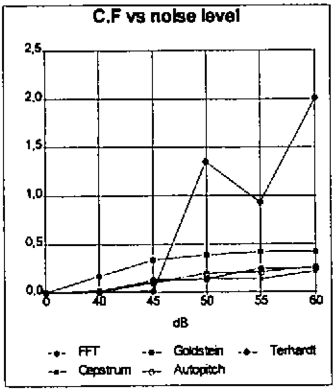


Fig 1. (a)

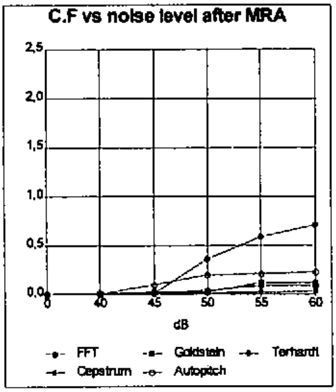


Fig 1. (b)

5. CONCLUSIONS

When noise level increase, the algorithms became to produce values more distant to the pitch of the signal whithout noise. Duifhuis's algorithm that implement Goldestein's model, was the more sensible to the noise presence. FFT algorithm, Cepstrum and Autopitch, always mantained a C:F coefficient smaller than C.F. coefficient of Goldstein. The Terhardt's algorithm at low noise level appreciate well the original picth, and at high noise level produce high values of C.F coefficient. The values of C.F coefficient decreased in all the algorithms after MRA was used. This show that the use of multiresolution analysis could suppose the improve of pitch evaluation in all the algorithms. Though C.F coefficient decrease, only the original pitch is well recovered when this coefficient is zero. Comparing Fig 1(a) with Fig 1(b), C.F coefficient reduction was obvious. The most important improve was produced in Goldstein's algorithm. The Terhardt's algorithm maintain its behaviour though its C.F coefficient decrease. Cepstrum algorithm decrease almost totally its coefficient.

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