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PROTOTYPE OF BRACELET DETECTION ALARM SOUNDS FOR DEAF AND HEARING LOSS

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ABSTRACT

Currently all technological progress should go in search of satisfying a need of society, in all contexts: health, work, study, etc. in this article we plan a prototype bracelet in the field of assistive technologies specifically for deaf or hearing loss people. the development of this prototype is able to discriminate sounds an alert or emergency, in addition to managing a user Interface quite friendly with additional features like Clock, alarm, among others. For the process of discrimination of sounds and alert detection system was used as a training tool, the Artificial Neural Networks (ANN). Was implemented for the microcontroller DSPIC33EP512GP502 microcontrollers. Previous tests demonstrate greater efficiency of 75% in identifying three types of sounds of emergency (ambulance, police, fire).

Keywords: ANN, bracelet, deaf, hearing loss, microtronller DSPIC33EP512GP502, assistive technologies, discriminate sounds.

1. INTRODUCTION

Today assistive technologies are a field in important development, the needs of people with different disabilities such as hearing, vision, mobility or other, live daily with a series of adversities that destabilize their quest for a quiet life and better quality. Science since its inception has sought and developed solutions in different contexts surrounding this situation, from medical advances such as surgery, treatments and medications to achievements in the field of engineering as different electronic elements, mechanical or similar which have resulted in an temporary or even permanent alternative to alleviate and overcome the various inconveniences with which they live.

Given these situations that arise, as researchers Surcolombiana University in compliance with one of its primary duties as an educational institution, we seek to develop a project that solutions to these problems in a particular and special, more specifically the obstacles so that live daily deaf or hard of hearing [1]. Then it will be the development of a project to improve the quality of life of this particular population, including in their daily lives using an electronic device that allows alerting of emergency and at the same time become an everyday tool discreet and friendly user profile looking to improve and give a more quality of life using the knowledge of engineering as the main tool.

Different feature extraction techniques for sound emergency signals and turn different methods for performing a sorter that allows indicate the type of emergency signal detected explored. Once carried out the relevant studies and from the results the best methods are selected based on their efficiency and computational cost.
To develop the characteristics extraction method [2] and selected classification is necessary to implement an embedded system that has the ability to perform signal processing in real time and in which to implement an artificial intelligence algorithm. For this we have taken into account the range of dsPIC microcontrollers from Microchip, selecting the reference DSPIC33EP512GP502. The decision to select this microcontroller is based primarily on their ability to work up to 70 MIPS, high performance ADC, DMA and especially an optimized library for DSP.

2. CHARACTERIZATION OF EMERGENCY SOUND SIGNALS

To simulate signals a professional siren loudspeaker for emergency vehicles was acquired 100W.En the realization of the prototype bracelet you have been selected beep three types of emergency: Police, Ambulance, Fire Brigade. Recordings were performed with a time of five seconds for each, with a sampling rate of 8000Hz. These recordings are made in MATLAB and then the spectrogram is obtained to observe these characteristics in time and frequency. Based on different recordings the following spectrogram patterns were obtained:

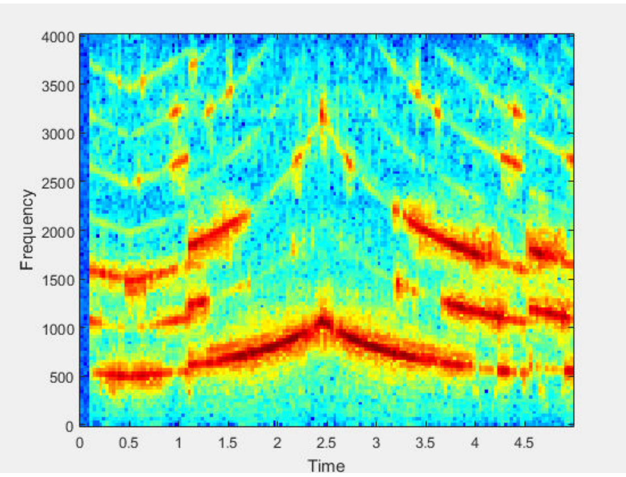

Figure-1. Spectrum representation of siren's ambulance.

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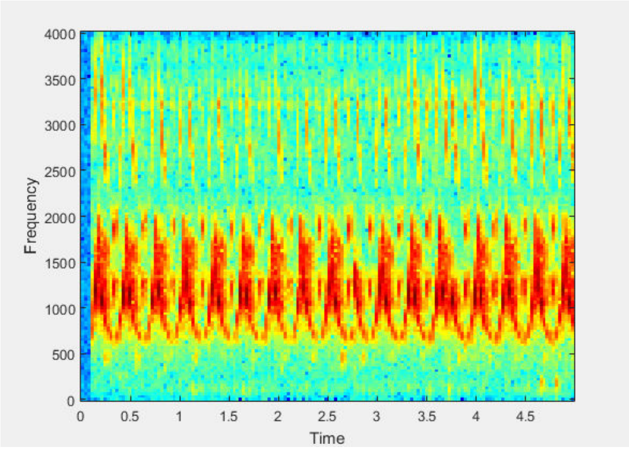

Figure-2. Spectrum representation of siren's police.

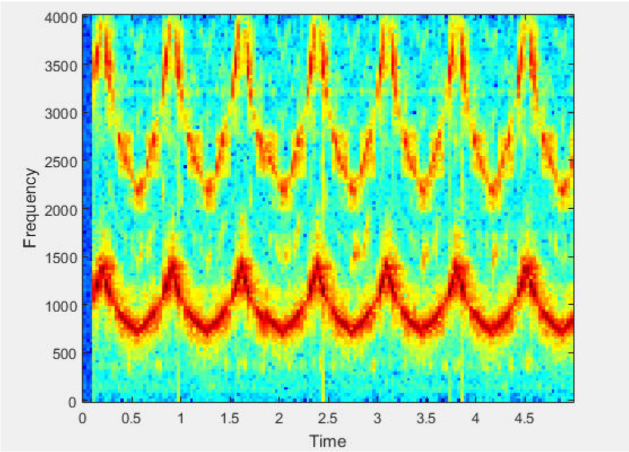

Figure-3. Spectrum representation of siren's ambulance.

From these results it can be inferred bandwidth for each of the sounds of emergency. Ambulance for signal was obtained which is in a range of 500-1100 Hz frequency spectrogram obtained according. As for the signal spectrogram Police by a range of 600-1500 Hz frequencies it was obtained. Finally for the signal corresponding to the frequency range Fire provided by the spectrogram of 700-1500 Hz is

Knowing the corresponding bandwidths for each emergency beep will be the starting point for the design of filters and parameters to be considered in feature extraction.

3. EXPERIMENTAL PHASE

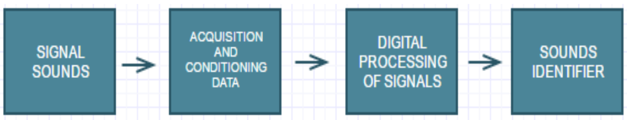

Figure-4. System block diagram.

Process Development and Implementation of prototype bracelet is summarized in the block diagram of the previous figure, as seen it all starts with getting the sound signals of different emergency sounds. We will continue explaining each of the following blocks of the system with its main processes and characteristics. In the first instance we will have an experimental phase in which we will rely on the MATLAB software as verifier of ideas for different feature extraction methods and algorithms for the performance of the classifier.

Acquisition and conditioning data

The first module of the system is to capture the signal where the process of acquisition and signal conditioning [3], which should be composed of an electret microphone bidirectional features amplification 100 is performed, allowing a signal output large enough to be digitized.

Figure-5. Microphone used for testing acquisition signals.

However, before making the acquisition and any signal conditioning it is vital to establish the sampling frequency with which they will design the filters and with which the ADC is configured for the sampling process and retention signals and further processing. For our purpose has selected a sampling rate of 8000Hz, which complies with the principles of Nyquist if we consider that the maximum frequency to be analyzed will be between 1350-1500 Hz.

Knowing the characteristics of the signals we wish to discriminate and set the sample rate, create a system of pre-filtering, specifically, the implementation of an antialiasing filter whose purpose is to eliminate any presence, prior to sampling the first instance above Fs / 2 frequency Fs being the sampling frequency. Therefore one often lowpass cutoff filter is designed 4000Hz.

Digital processing of signals and sounds identifier

The second module is the detection, where the digital signal processing is performed. This is done with the aim of analyzing the signal and search for audio segments that may contain events that are within the set of acoustic signals to identify.

Prior to feature extraction, independent of the method is to implement a digital filter to exclude ambient noise and other unnecessary frequency components for our purposes, so we get the signals in the frequency range where it is concentrated will hold its increased energy, which is between 500 Hz and 1350 Hz. from the above arises perform a corresponding digital lowpass filter with cutoff frequency of 1350 Hz, as well as one high-pass whose cutoff frequency is 500 Hz.

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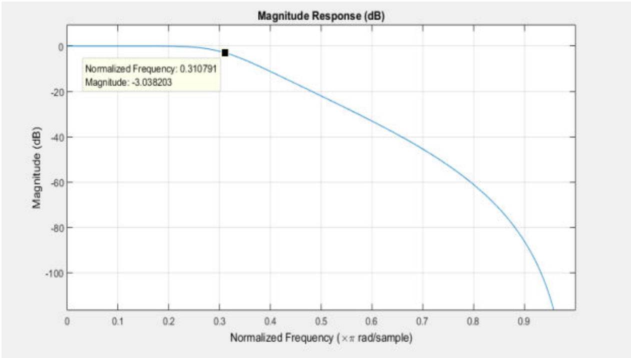

Figure-6. Frequency response of digital low pass filter.

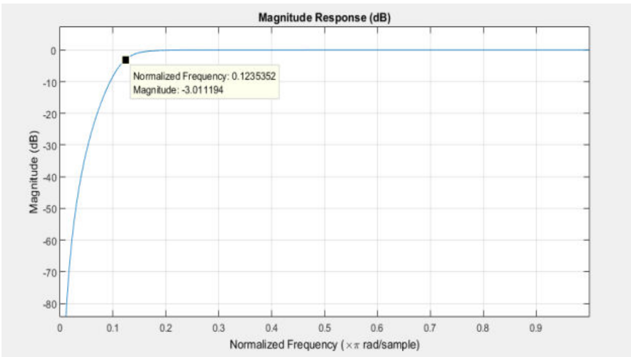

Figure-7. Frequency response of digital high-pass filter.

Despite the absence of any semantic to help the classification of alarm sounds, studies [4] in the field of recognition of sound signals show that working with a limited set of classes, certain parameters or characteristics of a signal given enough information so that it can be classified in a right way, even when the sound source to occur may be moving.

Then the development of several methods of feature extraction in conjunction with a technique that allows discrimination of the signals is presented.

Method 1: Fourier transform and ANN

The Fourier transform is a mathematical formula that relates a signal sampled in time or space to the same signal sampled in frequency. For a vector *x* that has *n* uniformly sampled points, the following formula defines the discrete Fourier transform (DFT) of *x*:

$$Yk + 1 = \sum_{j=0}^{n-1} w^{jk} x_{j+1} \qquad (1)$$

The fast Fourier transform (FFT) is a computationally efficient implementation of the DFT. While a one-dimensional DFT requires on the order of n^2 floating-point operations for a vector of *n* data points, the FFT requires on the order of *n*log*n* operations, a significant reduction in computational complexity. There are many specialized implementations of the FFT algorithm, such as ones that gain efficiency when *n* is a power of 2.

The methodology for the first method is as follows:

Figure-8. Feature extraction using FFT and obtaining matrix training.

In the first experienced method captures a buffer 4096 samples, second a little over half of audio signal, then this buffer is divided into frames of 512 samples, which are subjected to a filtering process using a filter Pasa IIR band in order to keep only the desired frequency components. After filtering the frame a process of windowing which helps narrow the spectral peaks or reduce the noise level, or apply a drift correction, which is to eliminate the DC level of the temporary signal to avoid spurious peak is done the spectrum. Once each Frame windowing the 512-point FFT is obtained. The data obtained in the transform are normalized between [-1, 1]. The above process is iterative to complete the processing of samples Buffer 4096. All the above-mentioned process is only for a second signal, the same is repeated to complete a training data set five second signal for each type of alarm.

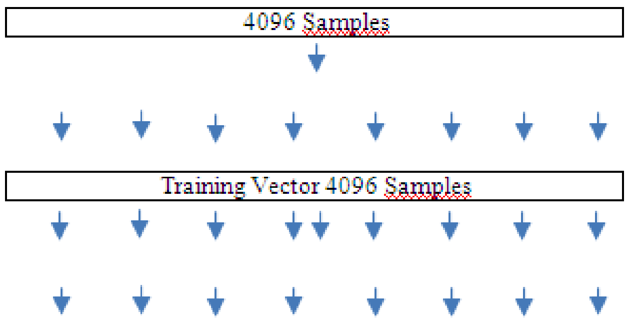

Figure-9. Vector processing buffer for method 1.

Para la detección automática en cuanto a la determinación de qué tipo de señal de Emergencia ha sido captada se opta por el uso de Redes Neuronales, para este caso en particular, una red Feedforwarden una de sus versiones especializadas conocida como Red de Reconocimiento de Patrones (patternet), la cual es básicamente una red que se para clasificar las entradas de acuerdo a los target de distintas clases. Las funciones de activación para este tipo de red son: Tansig para las capas ocultas y softmax para la capa de salida.

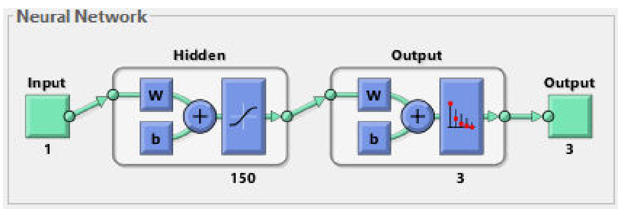

Figure-10. Topología de la red patternet utilizada.

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Método 2: Cepstrum y ANN

Para el segundo método se conserva la misma técnica para el reconocimiento automático a través de Patternet [5] y la misma topología usada en el método 1. La extracción de características se hace mediante un método de análisis frecuencial más complejo, denominado Cepstrum, cuyo algoritmo es en síntesis la Transformada inversa de Fourier del logaritmo de la magnitud de la transformada de Fourier de una señal.

La metodología para el segundo método será la Siguiente:

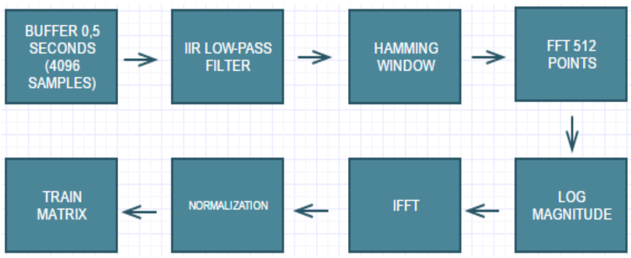

Figure-11. Extracción de características mediante Cepstrum y obtención de la Matriz de Entrenamiento.

512	512	512	512	512	512	512	512

512 HW	512 HW	512 HW	512 HW	512 HW	512 HW	512 HW	512 HW

FFT 512	FFT 512	FFT 512	FFT 512	FFT 512	FFT 512	FFT 512	FFT 512

En esta aplicación El cepstrum puede ser visto como una información del ritmo de cambio de las diferentes bandas de un espectro de las distintas señales sonoras de emergencia. [6]

Method 3: Spectrograph and RNA

3 methods for time-frequency analysis will be implemented. By STFT [7] Fourier analysis to each signal segment the signal resulting from cutting into time segments overlapping by use of a window is made. The meeting of the frequency content (frequency spectra) of each of these alternate segments called time spectrogram.

$$STFT_x(T,w) = \int_{-\infty}^{\infty} x(t)w * (t-T)e^{-j\omega t}\,dt \qquad (2)$$

Where ω denotes the frequency in a window w (t) about t = τ. The spectrogram is the magnitude squared of the STFT signal x (t).

$$Spectrogram, x(T,w) = |STFT_x(T,w)|^2 \qquad (3)$$

The methodology for the third method is as follows:

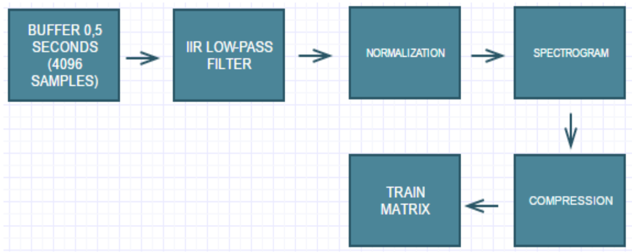

Figure-12. Removing features by obtaining Espectrogram and training matrix.

Prior to network training a compression algorithm for frequency bands 0-4000Hz dividing these frequencies in sub-bands interest applies. [8]

The technique used for automatic detection of the type of siren detected in this method differs from previous, continue using RNA but in this case the type SOM (Maps self-organized), this network is characterized by having an unsupervised learning. The activation function for this type of network is Compet transfer function for the output layer.

Method 4: MFCC's and cross correlation

As mentioned above statistical methods also are viable options for this particular process that we want to develop in the identification and discrimination of sounds, in our particular case we use the cross-correlation [9] of the MFCC's (Coefficients Ceptrales at frequencies of Mel) [10] as they are created to extract fundamental material characteristics of the components of an audio signal. The cross-correlation has enough work history and good results, and locking with MFCC's important literature that gave evidence of their effectiveness [11] was also found.

Our algorithm works as follows: we designed a database containing emergency sirens to work (Police, Ambulance and Fire) with our database as tearing his work with test signals pillar. We walked to work directly both the test signal input as we have in the database and perform the procedure and signal processing for the MFCC's respective of each (Fourier Transform filter bank Mel, Discrete Cosine Transform, etc). After having done this with the MFCC's of the worked signals, both the test and that of our database we apply the cross to find the similarity of these components correlation and where a higher level of correlation is found the algorithm provide us with a timely response to this search.

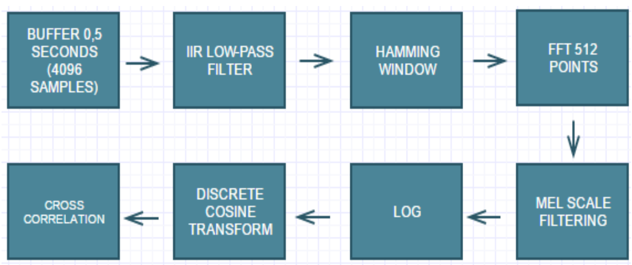

Figure-13. Feature extraction using MFCC's and cross correlation.

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It is clear that although the MFCC's are used mostly for recognition of audio speech, was considered working with them for their great efficiency in feature extraction, for 3 emergency signals as previously noted in the article have some similarities in their frecuenciales characteristics [12] applying careful detail to work them.

4. EXPERIMENTAL PHASE RESULTS

4 proven methods set, tested under different scenarios, have obtained the following results:

Table-1. Experimental results of the four methods used.

Method	Efficiency
FFT+ANN	40%
Cepstrum+ANN	60%
MFCC's+Correlación	50%
Espectrograma+ANN	75%

As competent to Method 1 (FFT + ANN) which in view of being implemented in hardware require little computational cost unfortunately no good performance. Tests were performed even increasing the number of points transformed without obtaining significant improvements. The main reason this method is so little efficiency this is that there are equal frequency components in the three target sirens (Ambulance, Police, Fire) and consequently conflict is presented in its discrimination by network pattern recognition.

For Method 2 (Cepstrum + ANN) initially a very low yield was obtained than expected, which improved dramatically increasing the number of points transformed to 1024, in this method at times results 90% efficiency were obtained under training one scenario, which would not be ideal, since the network only respond to that type of scenario and not a different situation. Finally, a performance hit on discrimination of only 60% which is still very low for our purpose was obtained. In addition to the low efficiency of the implementation of this would be impractical because the implement FFT and IFFT of 1024 points would require a large computational cost, in addition to this calculation Cepstrum requires the use of logarithmic operations, which occupy a considerable number of clock cycles in the microcontroller which significantly affect the real-time operation.

With respect to Method 3 (spectrogram + ANN) was reached at a yield of 75%, which we consider acceptable for our purpose. The main cause of obtaining better performance is due to the network topology is more complex as opposed to the network by pattern recognition, this network has 32 networks self-organizing maps composed of 6 Neurons each. The spectrogram applied using an FFT with 256 points Hamming window [13] of equal size transformed points. Besides the use of a complex network topology over a compression algorithm is applied frequency bands, as a result a more efficient by reducing the number of entries of each network training was achieved.

Finally in Method 4 (MFCC's + Correlation) reached a percentage of unsatisfactory performance for our aspirations. In each test scenario raised more complexity or some difference to original emergency signals sought. Generally only one of the test environments that work was completely successful and that does not meet the expectations to apply it as a definitive method of discrimination of sounds, especially when further analyzed the overall results none of the 3 averages correlation exceeds the threshold 0.6 (1 is the maximum) that would be "acceptable" range; of the 5 tests on each signal achievement police only pass the threshold of acceptable.

5. HARDWARE DESIGN

With the completion of the experimental phase and selected the corresponding spectrogram + ANN method is determined, the prototype of the bracelet. As mentioned in previous sections, the main axis of this device is the DSP, specifically the microcontroller DSPIC33EP512GP502. Their respective programming was done by MPLAB X and MPLAB C30 compiler.

Configuration and implementation DSPIC33EP512GP502 feature extraction algorithm

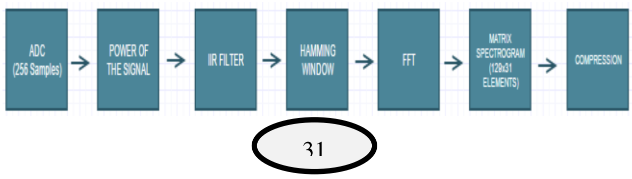

Figure-14. Digital signal processing captured in DSPIC 33EP512GP502.

Initially the device is configured to operate at 70 MIPS. After setting the speed at which the device is configured work the ADC to keep a buffer of 256 samples each interruption. Now comes an essential part of the operation of the device is the selection of the target signal, this means that the device will not be processed at all times, providing above all save battery. For the selection of the target signal the power of the captured signal is calculated, if this signal exceeds a certain threshold is given Home to feature extraction. The signal strength is calculated by the DSP Vector Power () function that provides the library <dsp.h> Microchip C30 Compiler. To start feature extraction buffer filtering is performed to rule out unnecessary frequency components of ambient noise and keep only the width corresponding to the emergency signals target band. The IIR filter is implemented by the DSP IIRTransposed () function. The next stage of feature extraction is to pass the Buffer Filtering by a Hamming window to save Ram memory microcontroller does not use the function that the compiler is done, for it created a Hamming window using the Software DSPIC works and we keep the window vector representative in program memory and then load it when necessary. Continuing the process of feature extraction reached the most essential part, the implementation of the FFT, this requires multiple procedures, starting load Twiddlefactors corresponding to the FFT of 256 points that want to implement, finally using the functions of the compiler FTComplexIP ( ), BitReverseComplex () and SquareMagnitudeCplx () the process of calculating the FFT is completed. Filter processes, windowing and FFT performed from the selection of the target signal are performed 31 times to complete a matrix 129x31 spectrogram corresponding to 1 second captured signal. Finally compression algorithm is implemented by frequency bands. Once completed the spectrogram iterates again attempt to register a target signal.

Training neural network and implementation within the DSPIC33EP512GP502

With the completion of the implementation of feature extraction we continued with the implementation of the discriminator alarms, in this case the neural network of self-organizing maps. With the extraction algorithm implemented features, various tests are performed under different conditions. With a sufficient number of training scenarios performed in MATLAB with dsPIC matrices obtained. Verified good network efficiency of the network weights is stored in the microcontroller memory and the algorithm of their respective activation function is implemented.

Visual interface and mechanics

With the aim of providing a device that meets the user in terms of comfort when carrying and handling the bracelet, we present a nice, simple interface to handle and of course allow transmitting the user visual and vibrational form alerts emergency surround it.

For the visual part it was decided to work with LCD display Nokia 6100 PCF8833 [14] and microntrolador of PIC18F4685 for programming all this control area such as the Motor Vibrator and RTC DS1302 [15] In order to providing a nice visual interface to the user based on a library-established Open Source drivers James P. Lynch allowed us to deploy the respective time and date on the display, in addition to designing a menu for setting the clock display battery status, adjust the contrast of the LCD and of course illustrative upon detection of an emergency signal alerts.

Figure-15. LCD Nokia 6100 PCF8833.

And playing more mechanical part stand 4 elements: Battery, vibrating motor, battery charger module and aesthetic design of the bracelet.

The chosen Battery: Lithium portable 3.7V and 1000mAh due to electrical characteristics of different devices and integrated to be used in the implementation of the bracelet. The vibrator motor is selected at a speed of 12,000 rpm, with a diameter of 10mm and a length of 3.4mm and weight 1.2g will be the one who turns the vibrating alarms when identifying sounds occur. The battery charger chosen was the TP4056 portable module [16]; its characteristics are appropriate and consistent for the operation that uses the different electronic elements of the bracelet.

Figure-16. Principal menu.

Figure-17. Emergency signal detection.

As for the design of the bracelet different models and options worked, this article will not present dimensions and precise information of the final prototype that was built because we are still looking better harmony of design, however we propose an image example of how looks a bracelet similar model because of its other features added as the clock.

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Figure-18. Similar model of prototype bracelet.

The differences of the final product with respect to the image are based on robust because with microphone and a pair of electronic elements this becomes thicker, but the idea and the main vision are very similar to this.

6. CONCLUSIONS

Although found little scientific literature conducted specifically in the field of identification and discrimination of sound emergency signals is achieved evaluate four different methods of feature extraction and three methods of discrimination. These were mainly selected its good track record in projects focused on voice and recognition of acoustic environments.

Focusing on results and seeking to obtain a device that works in real time taking into account the criteria of efficiency and computational cost method of feature extraction was selected by Spectrograph added to a compression algorithm data and discrimination by neural networks artificial self-organizing maps.

Hardware implementation Bracelet prototype has as the linchpin he DSPIC33EP512GP502 for performing the detection and discrimination algorithms, while for the visual and mechanical prototype interface the PIC18F4685 was selected to perform these tasks. This way you can implement a prototype bracelet assistive technology for people with hearing disabilities, which is characterized by low cost, an interaction with the simple and user friendly, with a design of acceptable and comfortable aesthetic that allows detection emergency signal as Ambulance, Police and Fire.

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