

Remote Tool for Heart Control and Diagnostic through Phonocardiography Signal

T. Mbiadoun Lionel¹, Kom Martin²

PhD Student, Department of Electrical Engineering and Telecommunication, Polytechnic, University of Yaounde I, Cameroon¹

Professor, Department of Electrical Engineering and Telecommunication, Polytechnic, University of Yaounde I, Cameroon²

ABSTRACT: In this work we present a tool that is able to help people living with heart problem. The device design as low cost module can help in country under development. The system is able to acquire PCG signal, store and transmit to a distant server. Data sent to the server are processed by the server situated in the health center. Result is then send to a physician and if an automate medication is available, it is send to the patient by the device through SMS. Finally the device will automatically arrange an appointment with a specialist according to the gravity of the case therefore the patient will be inform of the day and time by the device through SMS.

KEYWORDS: PCG, GSM, Heart, Telemedicine, ECG, Phonocardiography, Signal Processing, low cost.

I. INTRODUCTION

Health is one of the global challenges for the humanity. According to WHO [1], the highest attainable standard of health is a fundamental right for an individual. As the population of senior citizens and their chronic diseases increases, the number of people who need constant medical assistance also increases and daily monitoring of health-status related parameters is becoming important. Heart diseases in Africa are with HIV and malaria the first cause of death [2]. In those countries as in all poor country or country under development, the number of heart surgeons is very small and they are mostly concentrated in high density urban areas therefore people in villages are facing a lot of difficulties to contact a specialist for appropriate treatment. Electrocardiogram (ECG) are used by physicians in large majority in order to measure electrical current from the heart. It uses multiple leads attached to the patient's body in order to capture the electrical signal from the heart. This process can be painful for the patient, very expensive too. ECG are limited as they cannot detect specific cardiac anomalies (aortic stenosis, aortic regurgitation, mitral regurgitation, mitral stenosis and murmurs)[3] because the electrical signal generated by some very light mechanical activities of the heart are attenuated enough before reaching ECG sensors[4]. In this paper we used Phonocardiogram (PCG) which is a physiological signal reflecting the cardiovascular status that is easy to acquire, non-invasive, low-cost and make the test easy and very appropriate for African countries. The design system has three main blocks: Data Acquisition, Signal Processing & Remote Monitoring of heart sounds. This work will focus on the signal processing and transmission through internet to a specialize health center. The paper is organized as follows: a literature review on existing work, we give our methodology, experimental results and then a conclusion and perspectives.

II. LITERATURE REVIEW

a. HEART ANATOMY AND FUNCTIONING

The heart is a muscle that contracts continuously, from the first months of our conception until our death. In a lifetime, it will beat about 3 billion times. Its function is to pump and propel the blood to all the organs of our body. It pumps about 5 liters of blood per minute. Muscle of about 250 grams, located in the middle part of the thoracic cage delimited by the 2 lungs, sternum and spine. It measures between 14 and 16 cm for a diameter of 12 to 14 cm in And a

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

volume of 50 to 60 cm³[5]. The heart is composed of two distinct separate entities: the right heart and the left heart. Each heart is composed of a ventricle on the lower part and an atrium on the upper part, separated by the tricuspid valve for the right heart and mitral valve for the left heart. The inter-auricular septum is the septum separating the atria, the ventricular septum, the septum separating the ventricles. There is no connection of myocardial (muscular) tissue between atria and ventricles. Thus, no blood exchange between the upper part and the lower part is possible. The passage is unidirectional between the atrium and the ventricle and this via the heart valves.

The heart acts as a double pump. Each half of the heart works separately from the other. The right side of the heart is responsible for returning oxygen-poor blood to the lungs to remove carbon dioxide and reoxygenate the blood. The right auricle receives venous blood from the vena cava [6]. The blood is then propelled into the right ventricle. When the latter contracts, the blood enters the pulmonary artery and into the lungs. The pulmonary artery is the only artery in the body that carries blood that is low in oxygen. The left side of the heart receives freshly oxygenated blood from the lungs and redistributes it throughout the body [7].

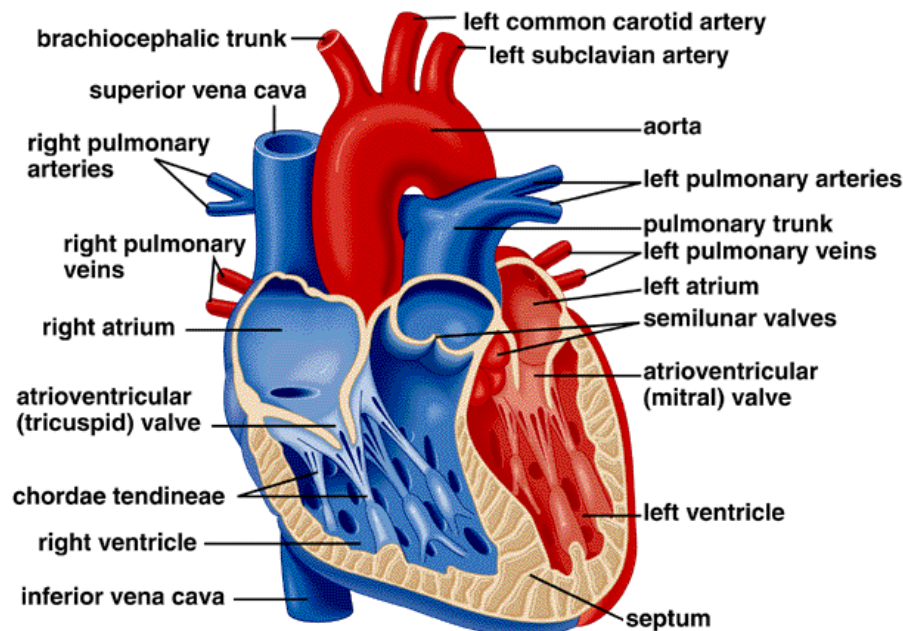


Fig 1: heart anatomy [8]

b. ELECTROCARDIOGRAPHY AND PHONOCARDIOGRAPHY

Electrocardiography is the recording of the electrical activity of the heart. It is done with 12-lead from which 10 electrodes are placed on the patient's limbs and on the surface of the chest. The overall magnitude of the heart's electrical potential is then measured from 12 different angles ("leads") and is recorded over a period of time. It picks up electrical impulses generated by the polarization and depolarization of cardiac tissue and translates into a waveform. The waveform is then used to measure the rate and regularity of heartbeats. A contact ECG signal (from skin) usually have a voltage amplitude from 0.5 to 4mV and a frequency from 0.01 to 250Hz [9].

Phonocardiography is the study of heart sounds. A Phonocardiogram or PCG is a plot of high fidelity recording of the sounds and murmurs made by the heart during a cardiac cycle. There are four: the first S1 when the atrioventricular valves close at the beginning of systole, the second S2 when the aortic valve and pulmonary

valve close at the end of systole, the third cardiac sound may be from either a ventricle or both ventricles, but most researchers attribute S3 to left ventricular wall vibrations at the fast filling period and the fourth S4 sound occurs at the end of the ventricular diastole, i.e. after atrial contraction and before the first sound of the heart. It is caused by the ventricular vibrations after the contraction of the atria. The PCG signal usually have a frequency between 20 to 500Hz and produce an extremely low sound that need adequate amplification.

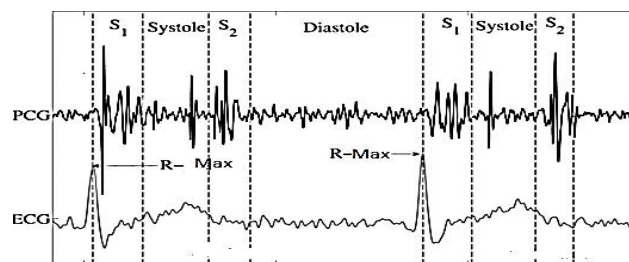


Fig2: Relation between ECG and PCG [10]

III. METHODOLOGY

a. SYSTEM ARCHITECTURE

The current technology in medical instrumentation is based on precision, reliability and robustness of various devices. Our system is based on a microchip microcontroller, responsible for coordinating and controlling all tasks necessary to acquire the PCG signal. For the sake of precision and simplicity, we use a digitally controlled C.A.G and we will use the tools developed by microchip for storage and transmission respectively SD click and GSM click.

Fig3 represents the synoptic of the device that will be connected to the patient at home. And it is made of 3 main part: The sensor which is an Electret microphone, The pre-treatment unit (pre amplificator, pass band filter and C.A.G) and finally the treatment unit which is the brain of the system and mad on PIC 18F4550 of microchip.

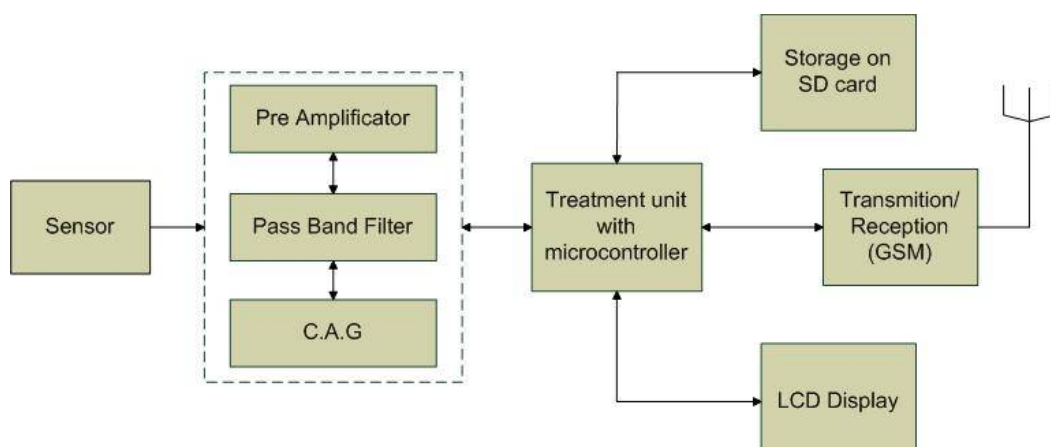


Fig3: Synoptic of the patient's system

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

Fig 4 represents a synoptic of the device that will be connected to the server at the competent health center. The analysis of the transmitted signal is done in three main stages known as Location, Segmentation and Classification. The phase of Localization of the Cardiac Signals consists of temporal localization of the first and the second cardiac sound (S1 and S2). After locating the first and second cardiac sounds, the next step is to detect the ends of each localized sound. This process, which represents the segmentation phase, aims to decompose the cardiac sound into four essential parts: S1, systolic phase, S2 and diastolic phase. This phase is essential in the analysis of cardiac sounds, which facilitates the classification task by providing the automatic classification system with qualitative and quantitative information on the different signal components.

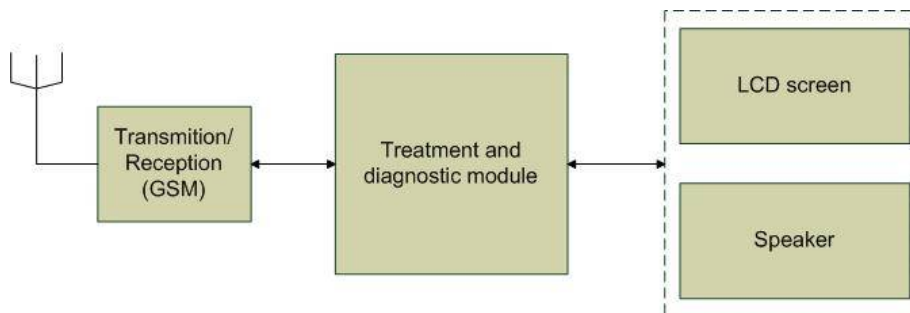


Fig4: synoptic of the health center's system

b. The S transform

The S transform was introduced in 1996 by Stockwell et al. [11] and realized a time frequency analysis of a defined signal and defined as follows:

$$S(\tau, f) = \int_{-\infty}^{\infty} h(t) \frac{|f|}{\sqrt{2\pi}} e^{-\frac{(\tau-t)^2 f^2}{2}} e^{-i2\pi f t} dt.$$

t represents the time and f the frequency of h signal.

The discrete version of the S transform is obtained by replacing τ by jT and f by $\frac{n}{NT}$

$$S[jT, \frac{n}{NT}] = \sum_{m=0}^{N-1} H[\frac{m+n}{NT}] e^{-\frac{2\pi^2 m^2}{n^2}} e^{\frac{i2\pi m j}{N}} \quad n \neq 0$$

N is the number of samples for $n=0$, S is given by

$$S[jT, 0] = \frac{1}{N} \sum_{m=0}^{N-1} h(\frac{m}{NT})$$

The inverse of discrete S transform is given by

$$h[kT] = \sum_{n=0}^{N-1} \left\{ \frac{1}{N} \sum_{j=0}^{N-1} S[jT, \frac{n}{NT}] \right\} e^{\frac{i2\pi n k}{N}}.$$

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

c. The modified SSE method

The SSE method calculate the Shannon energy of a local spectrum by the S transform. The formula introducing the Shannon energy is given by

$$SSE(t) = -\sum_{f=1}^N |S(t, f)|^2 \log(|S(t, f)|^2)$$

The envelope obtained by the SSE method is smoothed by a Butterworth low-pass filter. The SSE method has proved its robustness to noises coming from different sources, such as respiratory noise and ambient noise. The modification done is made on one parameter: α .

i. Gaussian windows with α parameter

The equation of the Gaussian window in the classical S-transform is given by

$$g(t, \sigma) = \frac{1}{\sigma(f)\sqrt{2\pi}} e^{-\frac{t^2}{2\sigma(f)^2}}$$

Using α parameter we have:

$$S^\alpha(\tau, f) = \frac{|f|}{\alpha\sqrt{2\pi}} \int_{-\infty}^{+\infty} x(t) e^{-\frac{(t-\tau)^2 f^2}{2\alpha^2}} e^{-i2\pi ft} dt$$

The introduced parameter α makes it possible to control the width of the Gaussian window in the time domain and in the frequency domain thus making it possible to find a value of α which maximizes the concentration of energies of the cardiac sounds.

ii. Algorithm

1. For any value of α between 0.5 and 2 with a step of 0.1, we process the corresponding S transform called $S_x^\alpha(t, f)$
2. A normalised step of S transform is apply

$$\overline{S_x^\alpha(t, f)} = \frac{S_x^\alpha(t, f)}{\sqrt{\int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} |S_x^\alpha(t, f)|^2 dt df}}$$

3. For any value of α , we calculate the following energy concentration:

$$CM(\alpha) = \frac{1}{\int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} |S_x^\alpha(t, f)| dt df}$$

4. The optimal value of α is the one that gives a maximal energy concentration

$$\alpha_{opt} = \arg \max(CM(\alpha))$$

5. The S transform that correspond to the optimal α is chosen

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

$$S_x^\alpha(t, f) = S_x^{\alpha_{opt}}(t, f)$$

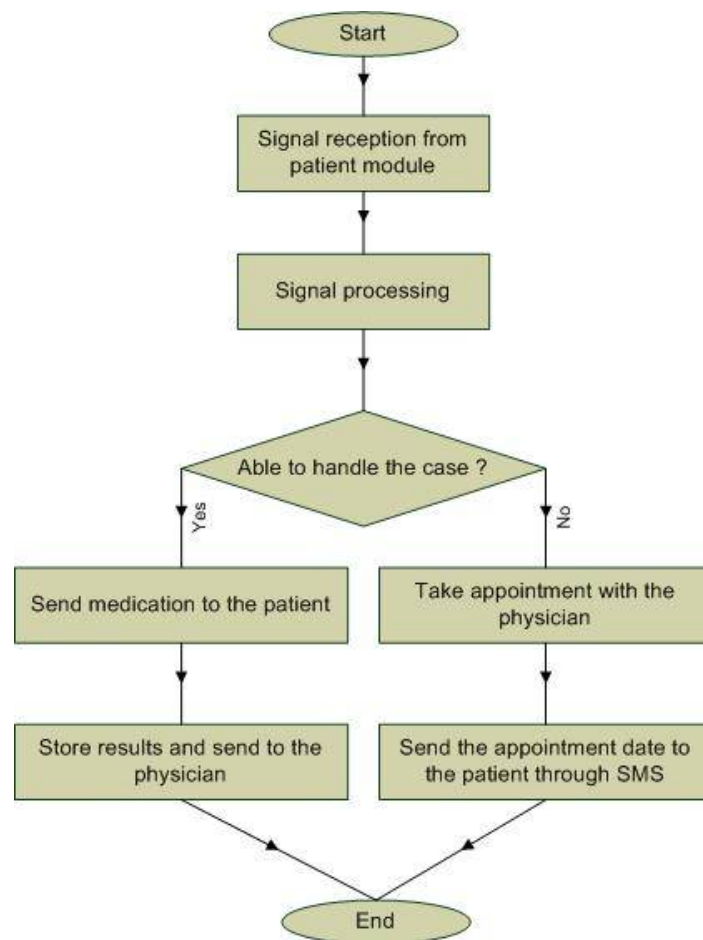


Fig5: Flowchart of the process

IV. EXPERIMENTAL RESULTS

The software made in the framework of our study was done under the program MATLAB R2010b for the simplicity of implementation. Indeed MATLAB is a mathematical calculation software already integrating a large number of mathematical functions and methods that facilitate the realization of programs in signal processing.

Fig 6 gives the general structure of the application in its main page, which consists of four essential parts: original signal, filtered signal, patient data, and operation result.

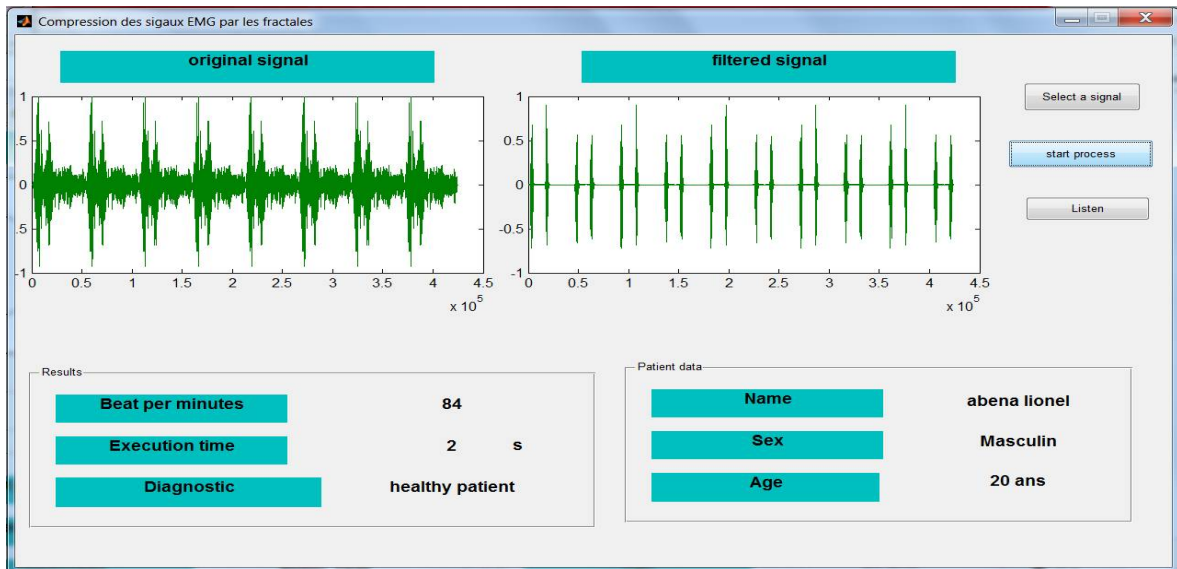


Fig6: Main window of the program

Fig 7 shows the main board of the module which is based on microcontroller 18F4550 from microchip. The device has an LCD display from nokia 5110 that shows devices working messages and also display results after and test is requested by the patient. The device is also able to receive and send messages to the server of the health center.

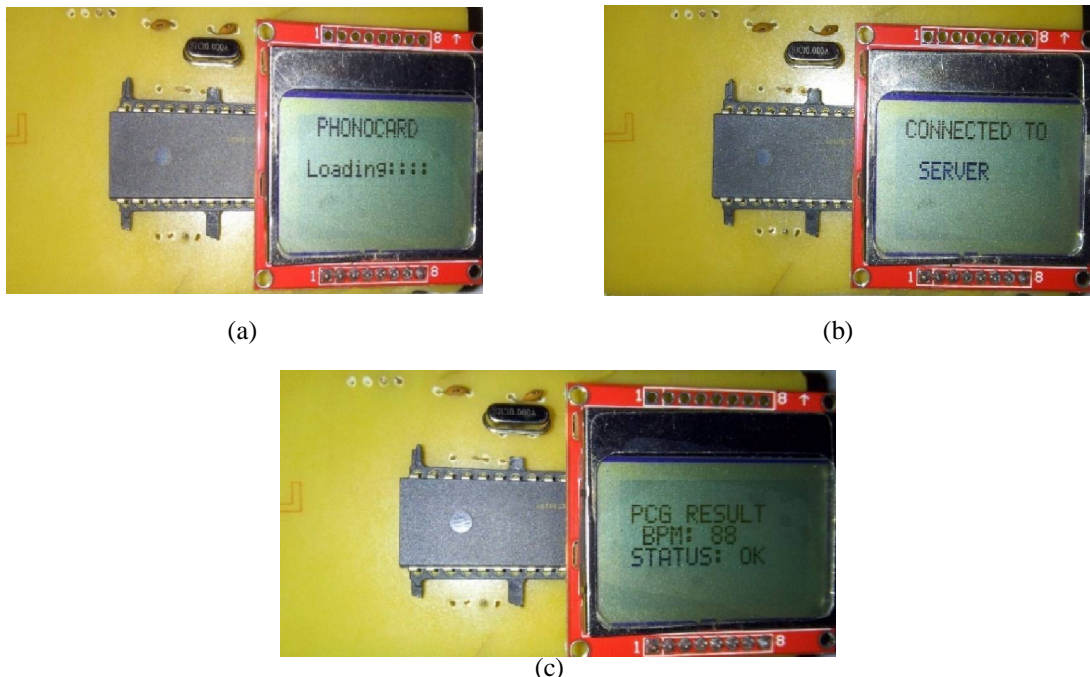


Fig 7: Main board of the device (a) Loading page (b) Connection to server (c) final result

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

V. CONCLUSION

In this paper we have developed a prototype of a device for diagnostic of hearth diseases through PCG signal. We have designed the circuit using the microcontroller 18F4550 which is the brain of our electronic device. A new algorithm to process PCG signal has be developed and give pretty good results. We have successfully acquire, store,send and process a sound heart. The system is completely automate and is able to perform all enumerates task without a human help. It can then be used as a watchdog that is there to catch any problem from a registered patient, give a prescription if possible. If the system is not able to give a medication, then it will arrange and appointment with a specialist and inform the patient.At the end of this work we can say that our objectives have been reached a 90%. As perspectives we have to reduce the size of the device and also ameliorate our algorithm for it to be able to identify more heart problem.

REFERENCES

- [1] World Health Organization, "Non communicable Diseases (NCD) Country Profiles", WHO press, Vol.1, pp1-210, 2014.
- [2] World Health Organization, "The Global Burden of Disease, Epidemiology and Burden of Disease", WHO press, Vol.1, pp1-160, 2003.
- [3] Mekhalfi, M. L., "analyse des signaux PCG par l'usage de la CWT et de la DWT", Magister Thesis, Vol.1, pp1-95, 2012.
- [4] Rangayyan, R. M., and Lehner, R. J., "Phonocardiogram signal analysis: a review", CRC Critical Reviews in Biomedical Engineering, Vol.15, pp. 211-236, 1988.
- [5] P. Brendan, "The Human Heart, A Basic Guide to Heart Disease", Lippincott Williams & Wilkins, Vol.2, 2007.
- [6] uOttawa, " Lecture on Anatomy of the heart.", Online Medical eCurriculum, Vol.3, 2010.
- [7] Thierry Verson, "Anatomo-physiologie", <http://t.verson.free.fr/>, Vol.2, 2005.
- [8] Sylvia S. mader "inquiry into life", Mc Gram Hill, Vol.8, 1997
- [9] Kung-Bin Sung, "Introduction to biomedical Engineering", intechopen.com, Vol.1, pp.20-67, 2007
- [10] T.Mbiadoun Lionel, Kom Martin, NtsamaEloundou Pascal, "Universal module of Acquisition and transmission of Electrophysiological signal", IJIRSET, ISSN: 2319-8753, Vol.3 pp.13767-13776, 2014.
- [11] Stockwell R.G., Mansinha L., Lowe R.P., "Localization of the complex spectrum: the S-transform", IEEE Trans. Signal Processing. Vol.4 pp.998-1001, 1996.