Database for the interpretation of phonocardiograms

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Abstract. Using LabVIEW software, we built a set of images corresponding to cardiac sounds associated to diagnosed cardiac diseases. This constitutes an image database which facilitates phonocardiograms interpretation, also we made the correlation with diseases and the possible causes.

1. Introduction
Phonocardiography is not a new topic in science however is very important in Cardiology and in Physics applied to medicine since it is a noninvasive and very low-cost procedure, that allows to quickly assess the cardiac health status of a person.

Scientific research in this topic generates new international publications every year.

Phonocardiograms (PCG) are images of the sounds emitted by heart. Thanks to the technological advances now is possible acquiring sounds and showing its images on the computer screen with relative facility. PCG are for the facultative a powerful support for diagnostic of cardiac diseases, very cheap and important because is a noninvasive technic and its possible implement it with portable equipment.

When heart is working during full cycle, systole and diastole, emits sounds caused by the movement of four valves: Mitral, Tricuspid, Pulmonal and Aortic, the blood fluid movement or by friction of cardiac tissue.

Phonocardiogram is a graphic of the amplitude versus time of acoustic wave. In an image all the set of sounds is easy visible, different picks produced by several sounds are seen, emitted in different times of cardiac cycle.

Obtained the phonocardiogram of a person the next question is its interpretation. It is necessary identify the several sounds, its location and duration, as well as correlate wave alterations with the several cardiac diseases and specific origin.

1.1. Background
There have been published some papers about historical background of phonocardiograms especially phonomecanocardiography and its importance in the academic training of cardiologist [1] – [5].

Also, there are papers that describe how is produced each sound appearing in the wave, that considered as normal as those indicative of some pathology [6] – [7].

In several epochs and lands, there have been proposed several methodologies trying to interpret PCG using complex mathematical algorithms [8]- [15].

There are papers published recently that propose other ways to interpret phonocardiograms, using visual and other methods based on information technologies, like image recognition, which not involve complex mathematical calculus for medical sector. [16]-[19].
By the other hand, there are available database of cardiac sounds at open access that are used to training cardiologist students like those given by Littmann [20].

Also, there has been an open invitation recently to cardiologic community to participate sending database of heart sounds, PhysioNet/Cinc Challenge 2016, some of them under the open access scheme [22] – [23].

2. Building a visual code to interpret the PCG
With the aim to build an interpretation code of PCG to diagnose a cardiac disease we performed this theoretical and experimental work

Using NI compacDAQ 9172 and acquisition card NI cRIO 9215, we captured cardiac sounds which were provided by open access scheme of Littmann [20], emitted by healthy and seek hearts with identified illness.

With LabVIEW software, it was elaborated a computer program which converts sound waves in images, which shows on the computer screen and stock them like a data file.

So, with Littmann sounds open access database, we constructed a set of images or phonocardiograms corresponding to different cardiac diagnostics.

3. Results
In figures 1 to 14 are showed, 500 ms, phonocardiograms obtained. At each figure is identified respective illness that can be correlated with the possible causes that induce it.

Case 1. Normal beat

![Figure 1. Normal heart](image1)

Figure 1 shows a PCG of a healthy heart, in which are only two principal peaks. We can hear with clarity only two types of sounds called S1 and S2, corresponding to the moment of simultaneous closing of Mitral and Tricuspid valves at the beginning of systole, and the moment of simultaneous closing of Aortic and Pulmonal valves at the beginning of diastole.

Case 2. Paroxystical. Second sound split in variable mode.

![Figure 2. It shows splitting of S2](image2)

![Figure 3. S2 Split is short](image3)

![Figure 4. Splitting is not short](image4)

Figures 2, 3 and 4 shows PCG of paroxystical S2 splitting. If there is a delay in the closing of the aortic and pulmonal valves, it produces a splitting in S2 in two very close sounds. Can be paroxystical, which means that distance between the split of S2 is variable depending on the moment when inhaling or exhaling. Paroxystical splits may appear when there are essential hypertension or aortic stenosis.
Case 3. Second sound fixed split

Figure 5 shows a PCG of S2 fixed split. In this case S2 splitting is ever equal. Occurs when there is a birth defect, in which there is a hole between the right and the left atrial cavities, called septal atrial

Case 4. First sound with click of aortic ejection

Figure 6 shows a sound after S1. This alteration presents a click of aortic ejection after S1 called S3. Second sound is shorter and acute than the first. This click is caused by the thick leaflet in Mitral valve or a congenital defect.

Case 5. Opening lash in S2

Figure 7 shows a sound after S2. When diastole starts, closer and after S2 occurs the opening lash. When opening, a thick leaflet of aortic valve a lash appears. It can be confused with a division of S2. This is also known as a four sound or S4.

Case 6. Third sound with gallop

Figure 8 shows that a third sound, S3, may appears at the beginning of the diastole. S3 is caused by sudden deceleration of blood flow from atrial to the left ventricle. There is a left dilated ventricle with thick walls and weak contraction. In adults indicates congestive failure.

Case 7. Fourth sound with gallop

Figure 9 shows that a fourth sound, S4, appears before the first sound, ending the diastole. S1 decreases in intensity and S2 increases. Is produced by an increase in the rigidity of the left ventricle caused by scar tissue. May be coronary pathology or very thick left ventricular wall caused by essential hypertension or aortic stenosis.
Case 8. Severe Mitral Stenosis

Figure 10 shows that S1 decreases in intensity due to the severe thinness of the leaflets of the mitral valve, S2 is normal. There are not additional sounds in the systole. There is an opening lash at 50ms in early diastole, shortening time in accordance with the severity of thickness. Later there is a low frequency murmur that lasts the rest of diastole. The first two thirds of the murmur have decrescent diamond form and the lasts are crescent. The volume of the Atrial is augmented, but amplitude of Mitral Valve movement is reduced. This disease is originated by rheumatism.

Case 9. Aortic Stenosis

Figure 11 shows the case in which S1 and S2 are normal. There is a murmur with diamond form, starts briefly after S1 and ends before S2. Murmur has a mid to high frequency. This disease is originated by a very thick ventricle. Leaflets of the aortic valve are thick and immobile. Murmur is due turbulent flow through stenosed aortic valve.

Case 10. Mitral Valve Prolapse

Figure 12 shows the case when there is a diamond form mid acute murmur that starts after a mid systolic click that goes to the end of systole. Murmur is originated by mitral valve leaflets prolapse and turbulent flow from the left ventricle to the left atrial.

Case 11. Patent Ductus Arteriosus

Figure 13 shows the case when S1 is normal and S2 is overshadowed by a continuous increasing-decreasing murmur that goes from the beginning of the systole to the end of diastole having its maximum to the end of the systole. There are an enlarged left atrium and ventricle and turbulent blood flow from the aorta artery to the pulmonal through the patent ductus.
Case 12. Rheumatic Aortic Stenosis

Figure 14 shows that S1 and S2 are normal but there is an aortic ejection click in the systole followed by a systolic murmur with diamond form. Also, there is a murmur with sharp, decreasing sound, that fills the first two thirds of the diastole.

The left ventricle is thin and the aortic valve leaflets are thin too, but in movement. There is moderate turbulent flow through the aortic valve in the systole and a little turbulent flow of regurgitation within the left ventricle in diastole. This turbulent flow of blood causes systolic and diastolic murmurs. It is a case of moderate aortic stenosis combined with aortic regurgitation in a person with rheumatic heart disease.

Case 13. Acute Pericarditis

Figure 15 shows the case when the first and second sounds are overshadowed by the noise of friction. The murmurs are caused by the turbulent flow of the blood through narrow valves. A pericardial friction caused by the friction of two surfaces of the pericardial sac is also heard. The pericardial friction has three components: one systolic, one early diastolic and one late diastolic.

4. Discussion

With the images obtained from heart sounds, it is possible to make a classification and correlation with heart diseases. In this work the following cases has been presented:

Normal heart, Paroxystical and fixed Split of the second sound, First sound plus click of aortic ejection, Second sound plus opening lash, Gallop of third sound, Gallop of fourth sound, Severe mitral stenosis, Aortic stenosis, Mitral valve prolapse and click with late systolic murmur, Patent Ductus, Rheumatic aortic stenosis, Acute pericarditis.

With the images shown in the figures 1-15, it is possible to build a bank of images of sounds associated with specific heart diseases which we may compare with the PCG of other patients to make a diagnosis.

5. Conclusions

Phonocardiography is a method of diagnosing heart diseases, based on Acoustic applied to the sounds emitted by the heart. It is a non-invasive method of low cost.

In this work, using LabView software and a set of heart sounds provided by Littman open access database, it was built a bank of images or Phonocardiograms corresponding to 14 heart diseases which constitutes a PCG image database.

This bank of images will be used for the interpretation of PCG of patients with undiagnosed heart diseases.

6. References

[1] Guadalajara B 2015 Gaceta Médica (México) 151 260-5
[2] Fishleder B 1966 Exploración cardiovascular y fonomecanocardiografía clínica (México: La Prensa Médica Mexicana)
[3] Einthoven W and Geluk M 1894 Die Registrierung, Der Herztöne. Pflügers Arch Ges Physiol 57-617
[4] Leatham A 1958 Auscultation of the Heart (London, Lancet) 2 7049 703-8
[5] Mangione S, Nieman L, Gracely E and Kaye D 1993 The teaching and practice of cardiac auscultation during internal medicine and cardiology training Ann. Intern. Med. 119 (1) 47-54
[6] Shaver J, Salerni R and Reddy P 1985 Normal and abnormal heart sounds in cardiac Diagnosis Part I: Systolic sounds Current Problems in Cardiology10(3) 1-68
[7] Reddy P, Salerni R, and Shaver J 1985 Normal and abnormal heart sounds in cardiac diagnosis, Part II: Diastolic sounds Current Problems in Cardiology10(4) 1-55
[8] Delgado E, Castaño AM, Godino II and Castellanos G 2007 IFMBE Proc 18, 202-206.
[9] Echeverry JD, López AF, López JF 2007 Scientia et Technica Vol XII no. 034 139-143.
[10] Guzmán Vargas L, Calleja Quevedo E, Angulo Brown F 2003 Fluctuation and Noise Letters. Vol. 3, No. 1 L83-L89.
[11] Guzmán Vargas L, Muñoz Diosdado A, Angulo Brown F 2005 Physica A 348 304-316.
[12] Guzmán Vargas L and Angulo Brown F 2003 Physical Review E 67, 052901
[13] Guzmán Vargas L, Calleja Quevedo E and Angulo Brown F 2005 Fractal Methods and Cardiac Interbeat Time Series. Revista Mexicana de Física 51 suplemento 2, 122-127
[14] Gavrovska A, Zaji G, Reljin I, Reljin B. 2013 Computational and Mathematical Methods in Medicine. Vol. 2013, Articulo ID 376152
[15] Clifford GD, Chengyu L and Moody B, 2017 Recent advances in heart sound analysis Physiological Measurement. 38E10
[16] Granados S J, Rodríguez J L, Velázquez A J M, Fernández Ch J L, Jurado D T, Tavera R F and López G G 2010 Phonocardiograph signals acquisition and analysis system Proc. of the 1st. International Congress on Instrumentation and Applied Sciences, Cancún, México
[17] Granados J, Tafera F, Velázquez J, López G, Hernández R and Morales A 2014 Memorias del V Congreso Nacional de Tecnología aplicada a ciencias de la salud (México)
[18] Granados J, Tafera F, Velázquez J, López G, Hernández R and Morales A 2015 Acoustic heart. Interpretation of Phonocardiograms by Computer J. Phys.: Conf. Ser.582 012057
[19] Granados J, Tafera F, López G, Velázquez J, Hernández R and López GA 2017 From Phonomecanocardiography to Phonocardiography computer aided. J. Phys.: Conf. Ser.792 012060
[20] Littmann. Sound Builder. 2000 App for Ipad. www.imedicalapps.com
[21] Chengyu Liu et al 2016 An open access database for the evaluation of heart sound algorithms. Physiol Meas 372181.
[22] Michigan Heart Sound Open Access Database www.med.umich.edu/lrc/psb/heartsounds/index.html
[23] PASCAL Heart Sound Open Access Database www.peterjbentley.com/heartchallenge